Energy Research and Development Division
FINAL PROJECT REPORT

SOLAR ENERGY AND THE MOJAVE DESERT TORTOISE

Improving Decision Support for Reviewing and Planning Proposed Projects

Appendices A - C

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APPENDIX A:

Data Inventory for the Desert Tortoise Spatial Decision Support System (2014)

Threat Type	Feature Class	Description	Data Source	Year
Agriculture	NV_Cropland_NyeCo		sent to Cat by Levi Kryder Nye Co. NV. 5/23/2012	2012
Agriculture	NLCD_2011_Swclip	Pasture/Hay and Cultivated Crops classifications from the raster file for land cover classification.	U.S. Geological Survey	2011
Air Pollution	CA_NitrogenDep	Provides a geography of annual nitrogen deposition throughout most of the state of California including locations where there are no measurement data. Supports study of effect of anthropogenic nitrogen on the structure and function of terrestrial ecosyste	University of California - Riverside	2007
Altered hydrology	ALTEREDHYDRO	Altered hydrology is the modification of the occurrence, distribution, and movement of water, such that natural water transportation, storage and evaporation processes are affected. Even small changes in the landscape can affect the habitat	The Redlands Institute, University of Redlands	2011
Aqueducts	SW_AqueductCanals_2013	Aqueducts & Canals in the Southwest US	ESRI® Data & Maps 2013	2013
Captive Release or Escape	CAPTIVERELEASE	Unauthorized Release or Escape of Captive Tortoises to the Wild is the release of captive-reared and/or wild-caught tortoises that have been in captivity. This threat is derived from Human Access.	The Redlands Institute, University of Redlands	2011
Coyotes & Feral Dogs	COYOTEFERALDOGS	Predators (non-raven) to the extent any of these are subsidized by human activities. This threat is derived from Aqueducts, Drought, Garbage and Dumping, Landfills, Military Operations, Motor Vehicles on Paved Roads, Tourism and recreation areas, and Urba	The Redlands Institute, University of Redlands	2011
Disease	DISEASE	Harmful pathogens and other microbes that may or may not be endemic to the ecosystem or region, may move through populations naturally, or be directly or indirectly introduced and spread by humans. This threat is derived from Drought, Unauthorized Release	The Redlands Institute, University of Redlands	2011
Drought	SW_Drought_Spring2014		NOAA	2014
Fire Potential	CA_FIRETHREAT	Fire Threat is a combination of two factors: 1) fire frequency, or the likelihood of a given area burning, and 2) potential fire behavior (hazard). These two factors are combined to create 4 threat classes ranging from moderate to extreme	California Department of Forestry and Fire Protection (FRAP)	2004

Fire Potential	SW_FirePotential2012	The wildland fire potential (WFP) map is a raster geospatial product produced by the USDA Forest Service, Fire Modeling Institute that is intended to be used in analyses of wildfire risk	Fire Modeling Institute, USDA Forest Service	2012
Fugitive Dust	FUGITIVEDUST		Redlands Institute, University of Redlands	2011
Garbage and Dumping	GARBAGEDUMPING		The Redlands Institute, University of Redlands	2011
Geothermal Energy Development	SW_GeoPowerPlants		Great Basin Center for Geothermal Energy	2010
Grazing	SW_Grazing_RU	A mosaic of state level data from the four Bureau of Land Management State GIS sites. The grazing allotmentspastures are Federal lands upon which private individuals graze livestock.	U.S. Department of the Interior, Bureau of Land Management	2009
Historical Fire	EAFB_HistoricalFires			2012
Historical Fire	AZStrip_Fires1980_2013	AZ Strip Fire History 1980 - 2013	Todd Calico. Bureau of Land Management, Arizona Strip District Office (BLM-ASDO)	2013
Historical Fire	SW_Fires_2012	Fire History Perimeters 2012	The Geospatial Multi-Agency Coordination Group (GeoMAC)	2012
Historical Fire	SW_Fires_2000_2012	Fire History Perimeters 2000 to 2012	The Geospatial Multi-Agency Coordination Group (GeoMAC)	2012
Historical Fire	CA_FIRES1878_2012	Perimeters for large wildfires CA, 1878-2012, National Park Service, Bureau of Land Management, and US Forest Service	CAL FIRE	2012
Historical Fire	CA_Fires_Rx_1900_2012	The "RXBURN" data layer contains perimeters from multiple agencies of various prescribed burns, with associated tabular data for responsible agency, contract number, project name, start date, and acres reported.	CAL FIRE	2012
Historical Fire	NV_Fire1910_2013_USFWS	Perimeters for large wildfires NV, 1910-2008, USFWS	Donald P. Harper, Nevada Fish & Wildlife Office, U. S. Fish and Wildlife Service, (702) 515-5254. don_harper@fws.gov	2013
Historical Fire	SW_Fires_2013		Fire History Perimeters 2012	2013
Historical Fire	UT_FireHistory_1976_2010	Perimeters for large wildfires UT, 1976-2010, BLM)	UT - BLM - Utah State Office	2010
Human Access	Human Use		The Natural Resource Ecology Laboratory, Colorado State University	2010
Human Access	SW_MilitaryOwnership2013	Military Installations in the Southwest US	BLM	2013

Invasive Plants	FOOTPRINTMODEL_EXOTIC	This model was constructed to model the risk of invasion by exotic plant species.Roads may directly influence exotic plant dispersal via disturbance during road construction or via alterations in soil regimes. Roads may also indirectly facilitate.....	USGS-FRESC Human Footprint, Steve Hanser and Matthias Leu	2008
Landfills	WEMO_Landfills		Redlands Institute, University of Redlands	2003
Landfills	SW_Landfills_HF		USGS-FRESC Human Footprint, Steve Hanser and Matthias Leu	2003
Landfills	Landfills_SGFO	Landfills in or near the Red Cliffs Desert Reserve, UT	Marisa Monger, GIS Specialist, St. George Field Office BLM. (435) 688-3288, mmonger@blm.gov	2012
Landfills	EAFB_BorrowPits			2012
Military Operations	ChocMtns_HighExplosiveAreas		Bobby Law, MCAS Yuma, Arizona	2012
Military Operations	EAFB_Sidewalks			2012
Military Operations	EAFB_RecreationAreas			2012
Military Operations	EAFB_TargetAreas			2012
Military Operations	EAFB_HabitatDisturbance			2012
Military Operations	EAFB_ExistingStructures			2012
Military Operations	EAFB_Airfields			2012
Military Operations	FtIrwin_DryLakesSprings_offlimits			2012
Military Operations	FtIrwin_DesertCymopterus_conservation			2012
Military Operations	FtIrwin_DT_LMMV_conservation			2012
Military Operations	FtIrwin_Slow_Go_slopes			2012
Military Operations	FtIrwin_No_Go_slopes			2012
Military Operations	FtIrwin_Airfield_ramp			2012
Military Operations	FtIrwin_Airfield_surface			2012
Military Operations	FtIrwin_CanopyPavilion_area			2012
Military Operations	FtIrwin_Median_area			2012
Military Operations	FtIrwin_PedestrianSidewalk_area			2012
Military Operations	FtIrwin_Road_area			2012
Military Operations	FtIrwin_Slab_area			2012
Military Operations	FtIrwin_Structure_existing			2012

Military Operations	FtIrwin_Vehicle_driveway_area			2012
Military Operations	FtIrwin_Vehicle_parking_area			2012
Military Operations	EAFB_BurrowingOwl_conservation			2012
Military Operations	EAFB_HeadStart_pens			2012
Military Operations	MCAGCC_Alt6_ImpactAreas			
Military Operations	SW_MilitaryOwnership2013	Military Installations in the Southwest US	BLM	2013
Mineral Development	CA_AbandonedMines		CA BLM	2007
Mineral Development	CA_ActiveMines	Active Mining Claims in the BLM California Desert District, October 2009	CA BLM	2009
Mineral Development	Moj_Mines_TOMS		CA Department of Conservation, Office of Mine Reclamation	2012
Mineral Development	SW_MineralLocationsDatabase2012		U.S. Geological Survey	2012
Mineral Development	Moj_Mines_SMARAII		CA Department of Conservation, Office of Mine Reclamation	2012
Mineral Development	NV_Mines_NBMG		Nevada Bureau of Mines and Geology	2012
Motor Vehicles Off Route	WEMO_OHV_ImpactAreas	Based on a BLM inventory of vehicle based disturbances calculated for the West Mojave Plan; parcels with a higher than average number of vehicle based disturbance that had a higher than average number of TCS	U.S. Bureau of Land Management, California Desert District	2003
Motor Vehicles Off Route	BLM_RT_co_em_kr_fr	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Coyote, El Mirage, Kramer, and Fremont subregions.	U.S. Bureau of Land Management, California Desert District	2005
Motor Vehicles Off Route	BLM_RT_NECO	Routes of travel, NECO Plan area	BLM	2000
Motor Vehicles Off Route	BLM_RT_NEMO		BLM	2003
Motor Vehicles Off Route	BLM_RT_rtslwm_prop_8587	This is the proposed route network published in the West Mojave Plan FEIS, Nov. 2004, for those areas outside the subregions inventoried in 2002-03	U.S. Bureau of Land Management, California Desert District	2003
Motor Vehicles Off Route	BLM_RT_su_rm_nr_ju	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Superior, Red Mountain, Newberry-Rodman, and Juniper subregions.	U.S. Bureau of Land Management, California Desert District	2004
Motor Vehicles Off Route	SW_OHV_Areas	The SW_OHV layer is a mosaic of state level data from the four Bureau of Land Management State GIS sites. This data is designed to display the Open/Closed/Limited boundaries of Off Highway Vehicle (OHV) areas.	U.S. Department of the Interior, Bureau of Land Management	2009

Motor Vehicles Off Route	BLM_RT_BeaverDamWash NCA	BLM Routes in the Beaver Dam Wash National Conservation Area	Utah Automated Geographic Reference Center	2009
Motor Vehicles Off Route	BLM_RT_Needles_April_20 13		U.S. Department of the Interior, Bureau of Land Management	2013
Motor Vehicles Off Route	RedCliffs_UtilityRoads		Cameron Rognan, 5-9-2012	2012
Motor Vehicles on Paved Roads	Roads_SnowCanyon		Susan Zarekarizi, the Lands Coordinator	2012
Motor Vehicles on Paved Roads	EAFB_Transportation			2012
Motor Vehicles on Paved Roads	FtIrwin_Roads			2012
Motor Vehicles on Paved Roads	MCAGCC_Roads			
Motor Vehicles on Paved Roads	RedCliffs_UtilityRoads		Cameron Rognan, 5-9-2012	2012
Motor Vehicles on Paved Roads	SW_Roads2013_ESRI_RU		ESRI	2013
Motor Vehicles on Paved Roads	DeathValley_Roads			2012
Motor Vehicles on Paved Roads	Roads_ASDO		BLM ASDO	2013
Motor Vehicles on Unpaved Roads	BLM_RT_BeaverDamWash NCA	BLM Routes in the Beaver Dam Wash National Conservation Area	Utah Automated Geographic Reference Center	2009
Motor Vehicles on Unpaved Roads	BLM_RT_co_em_kr_fr	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Coyote, El Mirage, Kramer, and Fremont subregions.	U.S. Bureau of Land Management, California Desert District	2005
Motor Vehicles on Unpaved Roads	BLM_RT_NECO	Routes of travel, NECO Plan area	BLM	2000
Motor Vehicles on Unpaved Roads	BLM_RT_NEMO		BLM	2003
Motor Vehicles on Unpaved Roads	BLM_RT_rtslwm_prop_858 7	This is the proposed route network published in the West Mojave Plan FEIS, Nov. 2004, for those areas outside the subregions inventoried in 2002-03	U.S. Bureau of Land Management, California Desert District	2003
Motor Vehicles on Unpaved Roads	BLM_RT_SNDO	This is a coverage of designated roads and trails located in the Coyote Springs, Gold Butte, Mormon Mesa, and Piute-Eldorado ACECs in the BLM Las Vegas Field Office.	BLM	2008
Motor Vehicles on Unpaved Roads	BLM_RT_su_rm_nr_ju	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Superior, Red Mountain, Newberry-Rodman, and Juniper subregions.	U.S. Bureau of Land Management, California Desert District	2004
Motor Vehicles on Unpaved Roads	BCCE_OpenRoads	This map depicts the open roads within the BCCE along with many of the closed roads. The road status is provisional and is the status as of 1 Feb 2008.	Lee Bice, Clark County Desert Conservation Program	2008
Motor Vehicles on Unpaved Roads	DeathValley_Roads			2012

Motor Vehicles on Unpaved Roads	FtIrwin_Roads			2012
Motor Vehicles on Unpaved Roads	MCAGCC_Roads			
Motor Vehicles on Unpaved Roads	Roads_SnowCanyon		Susan Zarekarizi, the Lands Coordinator	2012
Motor Vehicles on Unpaved Roads	NV_OHVTrails	Off road recreation trails in Southern Nevada	Southern Nevada Land Cruisers	2012
Motor Vehicles on Unpaved Roads	BLM_RT_Needles_April_2013		U.S. Department of the Interior, Bureau of Land Management	2013
Motor Vehicles on Unpaved Roads	RedCliffs_UtilityRoads		Cameron Rognan, 5-9-2012	2012
Motor Vehicles on Unpaved Roads	SW_Roads2013_ESRI_RU		ESRI	2013
Motor Vehicles on Unpaved Roads	Roads_ASDO		BLM ASDO	2013
Non-motorized Recreation	Trails_SnowCanyon			
Non-motorized Recreation	SW_Roads2013_ESRI_RU		ESRI	2013
Non-motorized Recreation	MOJ_SmallDevelopment_points2014	Small human developments that are disjunct from urban and suburban settings which may impact wildlife and endangered species.	USGS GNIS, National Atlas, Calif. Dept. Parks and Recreation, Mojave National Preserve, GeoCommunicator, AZ BLM, CA Dept. of Transportation, NPS, Joshua Tree NP, BLM Ridgecrest Field Office, USGS The Human Footprint in the West, Utah State Parks, Solar PE	Updated May 2014
Oil and Gas Development	CA_Pipelines_Gas		BLM California Desert District	2009
Oil and Gas Development	CA_Pipelines_Oil		BLM California Desert District	2009
Oil and Gas Development	NV_ROW_Ely		NV BLM	unknown
Oil and Gas Development	SW_OilGas		Great Basin Center for Geothermal Energy	2007
Oil and Gas Development	CA_Pipelines_Gas_SCG			
Open OHV Area Use	SW_OHV_Areas	The SW_OHV layer is a mosaic of state level data from the four Bureau of Land Management State GIS sites. This data is designed to display the Open/Closed/Limited boundaries of Off Highway Vehicle (OHV) areas.	U.S. Department of the Interior, Bureau of Land Management	2014
Paved Roads	DeathValley_Roads			2012
Paved Roads	EAFB_Transportation			2012
Paved Roads	FtIrwin_Roads			2012
Paved Roads	MCAGCC_Roads			
Paved Roads	Roads_SnowCanyon		Susan Zarekarizi, the Lands Coordinator	2012
Paved Roads	Roads_ASDO		BLM ASDO	2013
Paved Roads	RedCliffs_UtilityRoads		Cameron Rognan, 5-9-2012	2012

Paved Roads	SW_Roads2013_ESRI_RU		ESRI	2013
Potential Conversion	Moj_PotentialConversion_Oct2013	Wildlands Colorado Desert Preserves (8-21-12) erased	Redlands Institute, University of Redlands	2013
Potential Urban	In progress - Serene			2013
Railroads	SW_Railroad2013_ESRI	U.S. National Transportation Atlas Railroads represents a comprehensive database of the nation's railway system. Includes railway name and type.	ESRI® Data & Maps: StreetMap 2013	2013
Ravens	FOOTPRINTMODEL_CORVID	Model of habitat utilization by synanthropic avian predators: common ravens (Corvus corax), American crows (Corvus brachyrhynchos), and black-billed magpies (Pica hudsonia)	USGS-FRESC Human Footprint, Steve Hanser and Matthias Leu	2008
Shift in Habitat Composition/Location	SHIFTHABITATCOMP		The Redlands Institute, University of Redlands	2011
Solar Energy Development	SW_Existing_SolarSites		Redlands Institute, University of Redlands	2013
Storms and Flooding	STORMSFLOODING	Storms and flooding is extreme precipitation and/or wind events or major shifts in seasonality of storms. This threat has been modeled as a constant across the Mojave Desert due to the lack of data and lack of confidence in the modeling parameters.	The Redlands Institute, University of Redlands	2011
Surface disturbance	SURFACEDISTURBANCE	Surface disturbance is the Disruption or removal of surface soil and/or vegetation. This threat is derived from ………………see metadata.	The Redlands Institute, University of Redlands	2011
Temperature Extremes	TEMPEXTREMES	Temperature extremes is periods in which temperatures exceed or go below the normal range of variation, including heat waves and cold spells. This threat has been modeled as a constant across the Mojave Desert due to the lack of data and lack of confidenc	The Redlands Institute, University of Redlands	2011
Tourism and recreation areas	MOJ_SmallDevelopment_points2014	Small human developments that are disjunct from urban and suburban settings which may impact wildlife and endangered species.	USGS GNIS, National Atlas, Calif. Dept. Parks and Recreation, Mojave National Preserve, GeoCommunicator, AZ BLM, CA Dept. of Transportation, NPS, Joshua Tree NP, BLM Ridgecrest Field Office, USGS The Human Footprint in the West, Utah State Parks, Solar PE	Updated May 2014
Toxicants	TOXICANTS	Toxicants are the air- and water-borne toxic substances from mine tailings, illegal dumping of hazardous wastes, garbage/litter, and toxic spills. This threat is derived from ………….see metadata	The Redlands Institute, University of Redlands	2011

Unpaved Roads	BLM_RT_BeaverDamWash NCA	BLM Routes in the Beaver Dam Wash National Conservation Area	Utah Automated Geographic Reference Center	2009
Unpaved Roads	BLM_RT_co_em_kr_fr	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Coyote, El Mirage, Kramer, and Fremont subregions.	U.S. Bureau of Land Management, California Desert District	2005
Unpaved Roads	BLM_RT_NECO	Routes of travel, NECO Plan area	BLM	2000
Unpaved Roads	BLM_RT_NEMO		BLM	2003
Unpaved Roads	BLM_RT_rtslwm_prop_858 7	This is the proposed route network published in the West Mojave Plan FEIS, Nov. 2004, for those areas outside the subregions inventoried in 2002-03	U.S. Bureau of Land Management, California Desert District	2003
Unpaved Roads	BLM_RT_SNDO	This is a coverage of designated roads and trails located in the Coyote Springs, Gold Butte, Mormon Mesa, and Piute-Eldorado ACECs in the BLM Las Vegas Field Office.	BLM	2008
Unpaved Roads	BLM_RT_su_rm_nr_ju	This is the proposed route network published in the West Mojave Plan FEIS, February, 2005, for the Superior, Red Mountain, Newberry-Rodman, and Juniper subregions.	U.S. Bureau of Land Management, California Desert District	2004
Unpaved Roads	BCCE_OpenRoads	This map depicts the open roads within the BCCE along with many of the closed roads. The road status is provisional and is the status as of 1 Feb 2008.	Lee Bice, Clark County Desert Conservation Program	2008
Unpaved Roads	DeathValley_Roads			2012
Unpaved Roads	FtIrwin_Roads			2012
Unpaved Roads	MCAGCC_Roads			
Unpaved Roads	Roads_SnowCanyon		Susan Zarekarizi, the Lands Coordinator	2012
Unpaved Roads	NV_OHVTrails	Off road recreation trails in Southern Nevada	Southern Nevada Land Cruisers	2012
Unpaved Roads	BLM_RT_Needles_April_20 13		U.S. Department of the Interior, Bureau of Land Management	2013
Unpaved Roads	Roads_ASDO		BLM ASDO	2013
Unpaved Roads	RedCliffs_UtilityRoads		Cameron Rognan, 5-9-2012	2012
Unpaved Roads	SW_Roads2013_ESRI_RU		ESRI	2013
Urbanization	NLCD_2011_Swclip	Updated circa 2006 land cover layer (raster) for the conterminous United States	U.S. Geological Survey	2011
Utility Lines and Corridors	CA_UtilityCorridors	Location of Utility Corridors in the California Desert District	CA BLM, CDD, Larry LaPre	1999
Utility Lines and Corridors	NV_ROW_Ely	Oil & Gas ROW in the Ely BLM FO, NV	BLM NV	2007
Utility Lines and Corridors	UT_RCDRPowerLines	Power Lines in the Red Cliffs Desert Reserve, UT	Cameron Rognan, Wildlife Biologist, Red Cliffs Desert Reserve	2010
Utility Lines and Corridors	UT_RCDRUtilityLines	Utility Lines in the Red Cliffs Desert Reserve, UT	Cameron Rognan, Wildlife Biologist, Red Cliffs Desert Reserve	2010

Utility Lines and Corridors	West_EnergyCorridors	This layer represents areas which have been proposed as West-wide energy corridors for either the draft or final "Programmatic Environmental Impact Statement, Designation of Energy Corridors on Federal Land in the 11 Western States", November 2008.	Argonne National Laboratory	2008
Utility Lines and Corridors	West_Powerlines	Powerlines in the western United States. Data was obtained from the ICEBMP existing utility corridors data set.	SageMAP	2003
Utility Lines and Corridors	CA_UtilityLines	Location of Utility Lines in the California Desert District	BLM CDCA	unknown
Utility Lines and Corridors	NV_TransmissionLines	Powerlines in Southern Nevada	NV BLM SNDO & City of Boulder City	unknown and 2007
Utility Lines and Corridors	NV_TransmissionLines_SouthNye			2012
Utility Lines and Corridors	EAFB_TransmissionLines			2012
Utility Lines and Corridors	AZStrip_Powerlines_2013	This dataset portrays powerlines that are upon and adjacent to the BLM's Arizona Strip District.	Todd Calico. Bureau of Land Management, Arizona Strip District Office (BLM-ASDO)	2013
Utility Lines and Corridors	AZStrip_LeasesROW_2013	This dataset shows the location of uses authorized by the Lands and Realty Program within the Arizona Strip District. Uses include both linear and site type rights-of-way, long term permits, and leases.	Todd Calico. Bureau of Land Management, Arizona Strip District Office (BLM-ASDO), LR2000	2013
Wild Horse and Burros	SW_HerdManagementAreas2009		U.S. Department of the Interior, Bureau of Land Management	2009
Wild Horse and Burros	DeathValley_WildHorseBurro		Linda Manning, Death Valley National Park. 5/22/2012	2012
Wind Energy Development	SW_WindFarms_USGS2013	This data set provides industrial-scale onshore wind turbine locations in the United States through July 22, 2013, corresponding facility information, and turbine technical specifications.	U.S. Geological Survey	2013

Recovery Action	Feature Class	Description	Data Source	Year
Connect habitat (culverts/underpasses)	NO DATA			
Control dogs	NO DATA			
Decrease predator access to human subsidies	NO DATA			
Designate and close roads (travel management plan)	Moj_RA_CloseRoads	closed BLM routes from various desert management plans and closed roads in the Red Cliffs Desert Reserve	Cameron Rognan, 5-9-2012	2012
Environmental Education	Moj_RA_EnvironmentalEducation			
Environmental Education	Moj_RA_EnvironmentalEducation_line			
Fire management planning and implementation	NO DATA			
Increase law enforcement	Moj_RA_IncreasedLawEnforcement			
Install and maintain human barriers (preserves)	Moj_RA_TortoiseFencing			
Install and maintain human barriers (wildland-urban interface)	Moj_RA_TortoiseFencing			
Install and maintain tortoise barrier fencing	Moj_RA_TortoiseFencing	A compilation of known AZ, NV, CA, and UT desert tortoise fencing.	Jill S. Heaton, University of Nevada, Reno	2009
Install and maintain tortoise barriers (open OHV areas)	NO DATA			
Land Aquisition	TWC_DesertAcquisitions	Wildlands Conservancy Desert Acquisitions representing the various land acquisition phases since 1999. Includeds pending residual Catellus land transfer.	The Wildlands Conservancy	2009
Land Aquisition	DFG_AcquisitionParcels	USE BUT DO NOT SHARE OR POST TO DATA EXPLORER. This dataset is intended to provide information on the location of lands owned and/or administered by the Department of Fish and Game and for general conservation planning within the state.	California Department of Fish and Game	2012
Land Aquisition	DTPC_AcquisitionParcels	Desert Tortoise Preserve Committee owned property in Kern, San Bernardino, and Riverside counties. USFWS NOTE: Data recieved from Mary Kotschwar, Desert Tortoise Preserve Committee, Inc. 5-9-12. Last geometry update appears to be June 2011.	Desert Tortoise Preserve Committee	2011
Land Aquisition	CA_BLM_Aquisitions20130930		CA BLM	2013
Land Aquisition	DCP_LandAcquisitions		Lee Bice, Clark County Department of Comprehensive Planning. June 24, 2014	
Landfill management	NO DATA			

Manage disease in captive population (permitting)	NO DATA			
Manage disease in wild population	NO DATA			
Minimize wild horse and burro impacts	NO DATA			
Protect intact desert tortoise habitat	NO DATA			
Remove grazing (close allotments)	SW_Grazing_RU	A mosaic of state level data from the four Bureau of Land Management State GIS sites. The grazing allotmentspastures are Federal lands upon which private individuals graze livestock.	U.S. Department of the Interior, Bureau of Land Management	
Restore Habitat	Moj_RA_RestoreHabitat_line			
Restore habitat (garbage clean up)	NO DATA			
Restore habitat (toxicants/unexploded ordinance)	NO DATA			
Restore roads (vertical mulching-roads)	Moj_RA_VertMulchPoints			
Restrict OHV events	NO DATA			
Sign and fence protected areas	Moj_RA_SignFenceProtectionAreas			
Sign Designated Routes	Moj_RA_SignDesignatedRoutes	Open Routes signs within the BLM West Mojave Planning Area (WEMO) placed at intersections and end points of BLM designated open routes to estimate the spatial location of already installed "open route" signs	Bureau of Land Management, Barstow Field Office	2011
Speed limits	NO DATA			
Targeted predator control	NO DATA			
Withdraw mining	Moj_RA_WithdrawMining			2012

APPENDIX B:

Report to the Renewable Energy Action Team, Sept 2013: *Applying a Spatial Decision Support System to Calculate Mojave Desert Tortoise Mitigation Action Ratios for the Desert Renewable Energy Conservation Plan*

Applying a Spatial Decision Support System to Calculate Mojave Desert Tortoise Mitigation Action Ratios for the Desert Renewable Energy Conservation Plan

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Abstract

The Desert Tortoise Spatial Decision Support System (SDSS) models:

- The effects of threats on tortoise populations (i.e., which threats cause other threats, and how these threats increase stresses on tortoise populations); and
- Recovery action-to-tortoise population relationships (i.e., what are the benefits to tortoises of actions given a set of population stresses faced by the species).

The SDSS relies primarily on the conceptual model, expert weights, and GIS data of the spatial extent of threats and recovery actions to calculate risk to tortoise populations resulting from threats, which can be decreased by undertaking recovery actions within tortoise habitat. An interactive version of the complete conceptual model with weights is publicly available online (http://www.spatial.redlands.edu/dtro/modelexplorer/). An interactive version of the complete library of GIS datasets used in the Desert Tortoise SDSS is also available online (http://www.spatial.redlands.edu/dtro/dataexplorer/).

To calculate acquisition-based management action mitigation ratios for the Desert Renewable Energy Conservation Plan (DRECP), we used the SDSS to estimate:

(1) Baseline risk to the desert tortoise from existing threats in the three recovery units in California
(2) Decrease in risk to the tortoise resulting from potential recovery actions implemented within the DRECP reserve area for each recovery unit
(3) Variance in the mitigation ratios associated with estimates of decrease in risk

1.0 Estimation of baseline risk to the desert tortoise from existing threats

1.1 Conceptual Model

The conceptual model, which is the backbone of the desert tortoise SDSS (Murphy et al. 2008, Darst et al. 2013), encapsulates scientific hypotheses about how the complex network of threats and recovery actions affect desert tortoise populations, as recorded in the revised Recovery Plan (USFWS 2011). The model employs a standard lexicon for biodiversity conservation (Salafsky et al. 2008), which defines and provides a list of potential threats, stresses, and conservation actions. This lexicon provides common elements that can be linked in a causal chain to represent a hypothesis about how actions are expected to bring about desired outcomes.

For each threat, an individual sub-model was created. We then connected the set of threat sub-models so that the direct and indirect effects of all threats to the species were captured in a single network (Darst et al. 2013; Figure 1). This network included population effects and two life stages (change in adult mortality, change in juvenile mortality, change in reproductive output, and change in immigration/emigration rates). Linkages in the network indicate relationships that can potentially be affected by application of recovery actions.

Weights were elicited from a variety of experts for every link in the model (Darst et al. 2013). For most nodes, a weight indicates the relative contribution of that node to the node to which it and its fellow nodes contribute (e.g., the contribution of a threat to a particular stress relative to the other threats that contribute to that same stress). The assessments were worded so that the experts were asked to estimate the range-wide contribution of one threat to another threat, of a threat to a stress, or of a stress to population effect. To quantify the weights for the relationships between population effects and overall population change, we used elasticity values from an existing population viability analysis for desert tortoises (Doak et al. 1994) that was adjusted to reflect one reproductive and one non-reproductive life stage (Darst et al. 2013).

All of these conceptual relationships and weights are captured, managed and documented using a Conceptual Model Manager tool. The Conceptual Model Manager displays a representation of the threats-based desert tortoise conceptual model and could be utilized for other species (http://www.spatial.redlands.edu/cmm/).

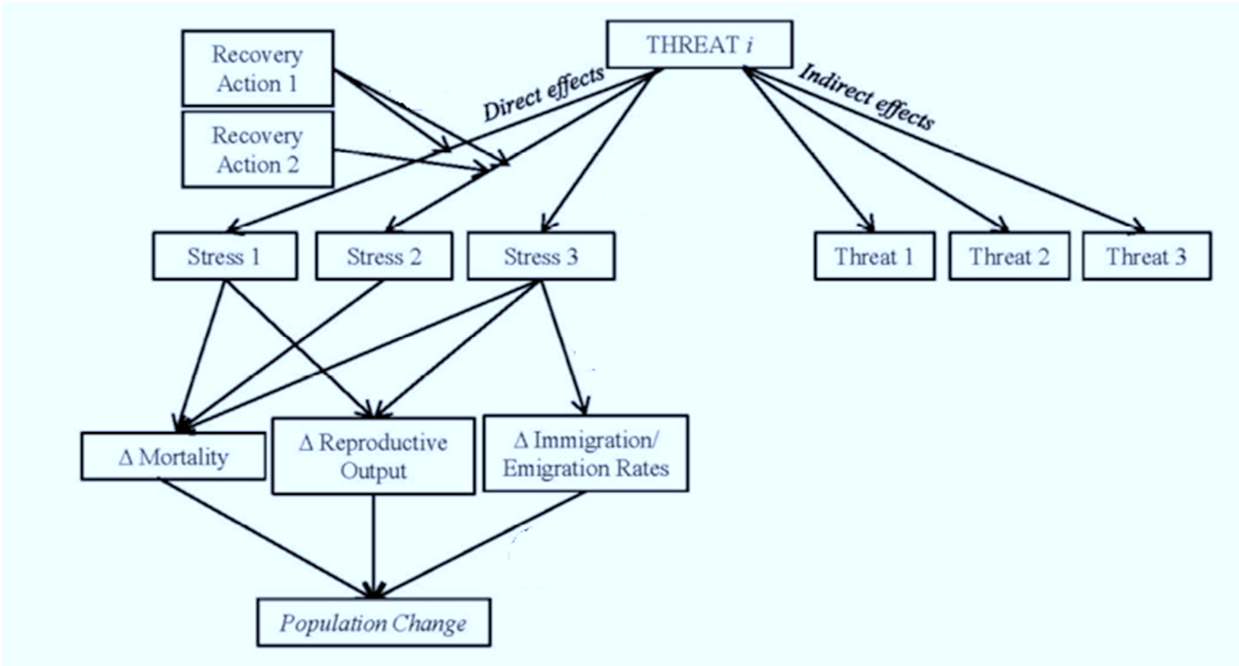


Figure 1. Conceptual Model Structure in the SDSS. Source: Darst et al. 2013.

1.2 Computational Models

The Desert Tortoise SDSS employs the following spatial representation and computational models:

- *Spatial Threats-based Population Change Model*: combines spatial data with the weighted network of threat to population change models to estimate the contribution to population change from all threats at every point on the range.
- *Risk to Population Model*: modifies the contribution of threats to population change by the probability of whether a tortoise is likely to occur at that location on the landscape.
- *Recovery Action Effectiveness Model*: estimates effectiveness of recovery actions in suppressing threat-stress links (i.e. mechanisms).

1.3 Spatial Computations of Risk to Population

Each threat in the Desert Tortoise SDSS model corresponds to a range-wide map layer whose value at each point represents the intensity of the threat at that point. This *threat intensity layer* is either an extent (a footprint) or a map layer with differing values at different points. In the former case the threat intensity values would be binary, encoding as 1's and 0's indicating the presence or absence of a threat at a location. In the latter case, the threat intensity values would be continuous, represented as a road category, a density of ravens, or the number of fires recorded in that area. In any given area, the different threats are more or less present according to their spatial distributions. However, each threat intensity map could be on a different scale, complicating direct comparisons of the contribution from different threats.

1.3.1 Normalizing the Input Threat Layers to Preserve the Meaning of Elicited Weights

To use the elicited weights in the conceptual model for system calculations, all threat intensity maps were converted to commensurate scales. We employed a standard approach from (a-spatial) decision analysis called Analytical Hierarchy Process (AHP; Golden et al. 1989, Saaty 1992, Saaty 1999), where each threat intensity map layer is normalized. This involved converting the original scale of a criterion, regardless of its units, to a scale where all the alternatives' values on that rescaled criterion now sum to 1.

Following this AHP methodology, the SDSS calculated a normalization factor for each threat intensity layer as the sum of the intensity values of the threat layer at each point over the entire range. We then divided the values of the original threat layer by the normalization factor to create the normalized threat layer, whose values are now dimensionless and when summed over the entire range, sum to 1. This approach guaranteed that if the experts estimated that a threat contributes a percent *w* to a stress, then when the normalized threat map layer, multiplied by that weight *w*, is summed over the entire range, it does indeed account for *w* of that range-wide stress.

1.3.2 Calculating Stresses in the Population Caused by their Contributing Threats

A threat may be localized, but its impacts, whether contributing to other threats or directly to stresses, may cover a larger area. For example, a mine may be localized, but it can contribute to fugitive dust over a larger area. Based on the literature, we assigned buffers to those contributing links where such an ecological effects area applied. No such extended effects were used for stresses contributing to population effects, or for population effects contributing to population change. Incorporating ecological effects areas required an extra step in the spatial calculations, in which the system generated a normalized threat ecological effects layer where applicable (Figure 3, Figure 4). Some recovery actions may also have an ecological effects area beyond where they are implemented. For example, roadside tortoise fencing can benefit populations a mile from the road (Boarman and Sazaki 2006).

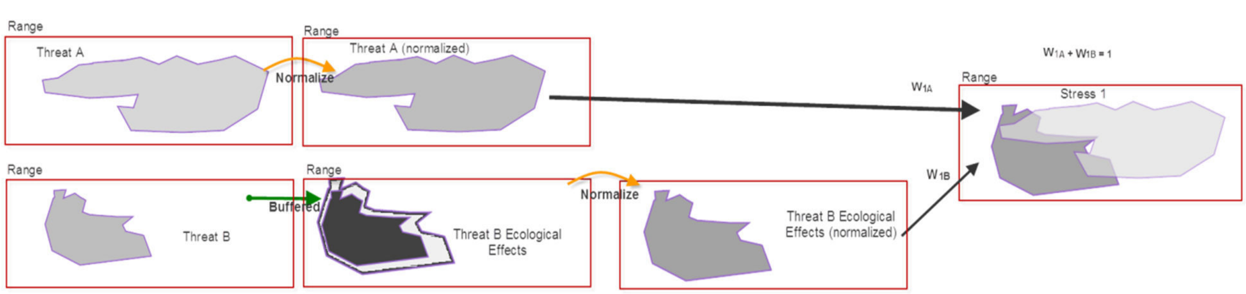
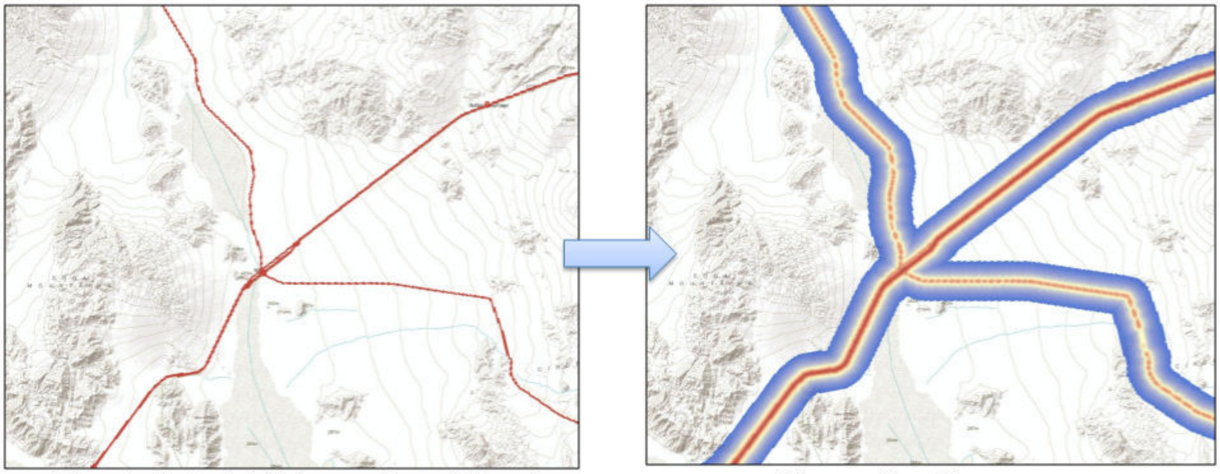


Figure 2. Spatial Calculation for the Normalized Ecological Effects Area Layer. Calculating Stress 1 from contributing Threats A (T_A) and B (T_B). Threat B has an ecological effects area greater than its intensity

footprint. Experts estimated that threats TA and TB contribute to Stress 1 with relative weights W1A and W1B respectively. Source: Murphy et al. 2013.

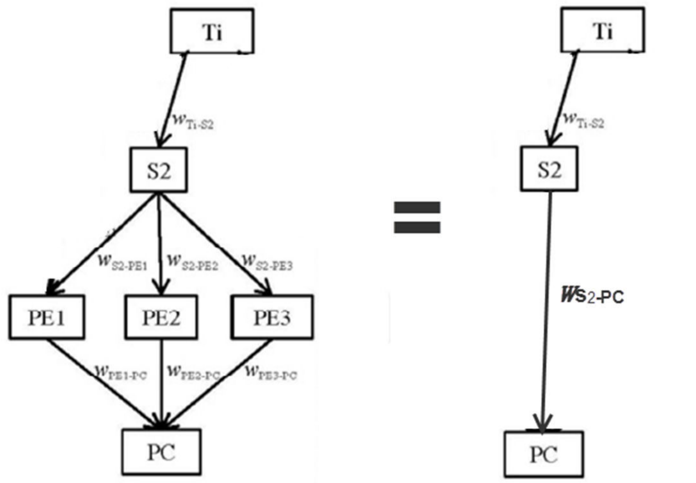


Threat: Motor Vehicles on Paved Roads *Stress: Crushing*

Figure 3. Example of Ecological Effect Area. The threat of "Motor Vehicles on Paved Roads" contributes to the stress of "Crushing" with a threat effects area of ~1 mile on each side of the road. The intensity of the contribution depends on the road classification: more heavily used roads contribute more to the overall threat intensity.

1.3.3 Contribution of a Direct Weight of a Stress to Population Change

Because a threat may have an ecological effects area when it contributes to a specific stress, we created spatial stress layers as in Figure 3, and then calculated a direct stress weight representing the contribution of a stress to population change (Figure 4). The direct stress weight summed the products of individual weights along the paths that linked that stress to population effects, and the population effects to population change.



$$W_{S2\text{-}PC}=(W_{S2\text{-}PE1}*W_{PE1\text{-}PC})+(W_{S2\text{-}PE2}*W_{PE2\text{-}PC})+(W_{S2\text{-}PE3}*W_{PE3\text{-}PC})$$

Figure 4. Calculation for a Direct Stress Weight from Individual Weights**.** The direct stress weight WS2-PC is the sum of the product of all weights along each path from the Stress S_2 to population change (PC). In this example there are three such paths. Source: Murphy et al. 2013.

1.3.4 Spatial Computation of Contributions to Population Change

The system estimates risk as contribution to population change at every point within the range. Each stress layer was multiplied by the direct stress weight and all values were summed to arrive at the contribution to population change at each point on the map (Figure 5). This approach does not estimate the *absolute* change in population, but rather the *relative* contribution of threats to whatever population change is occurring and thus the contribution to risk to the population.

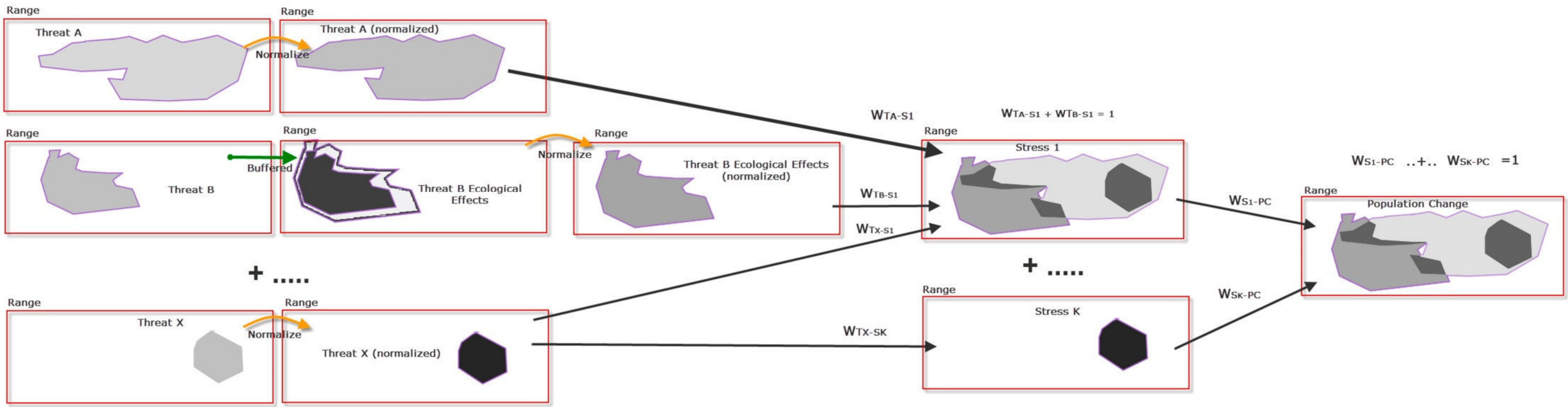


Figure 5. Spatial Calculation of Contributions to Population Change from Threat Intensity Layers. Source: Murphy et al. 2013.

1.3.5 Incorporating Probability of Presence into Risk Calculations

In the absence of an observed range-wide population density surface, we incorporated the heterogeneous distribution of tortoises across the landscape into the risk calculation by including the probability of tortoise presence. The value of the probability of presence surface at a point indicates how suitable that area is for desert tortoises. For areas with a high (close to 1) value but no current desert tortoise population, in the future a population may return and thrive there, a critical consideration in terms of species recovery.

To estimate current probability of presence, we used the U.S. Geological Survey (USGS) habitat potential model (Nussear et al. 2009). The USGS model reflects historic or pre-human-altered habitat potential based on environmental variables. From this, we subtracted "impervious surfaces," as defined by the National Landcover Dataset (Fry et al. 2011). All impervious surfaces were set to zero probability of desert tortoise presence. If there were areas of potential habitat smaller than 247 acres (1 km^2) surrounded by areas of zero habitat potential, these areas were also set to zero probability of desert tortoise presence since it was unlikely that these "islands" could be accessed by tortoises (Figure 6).

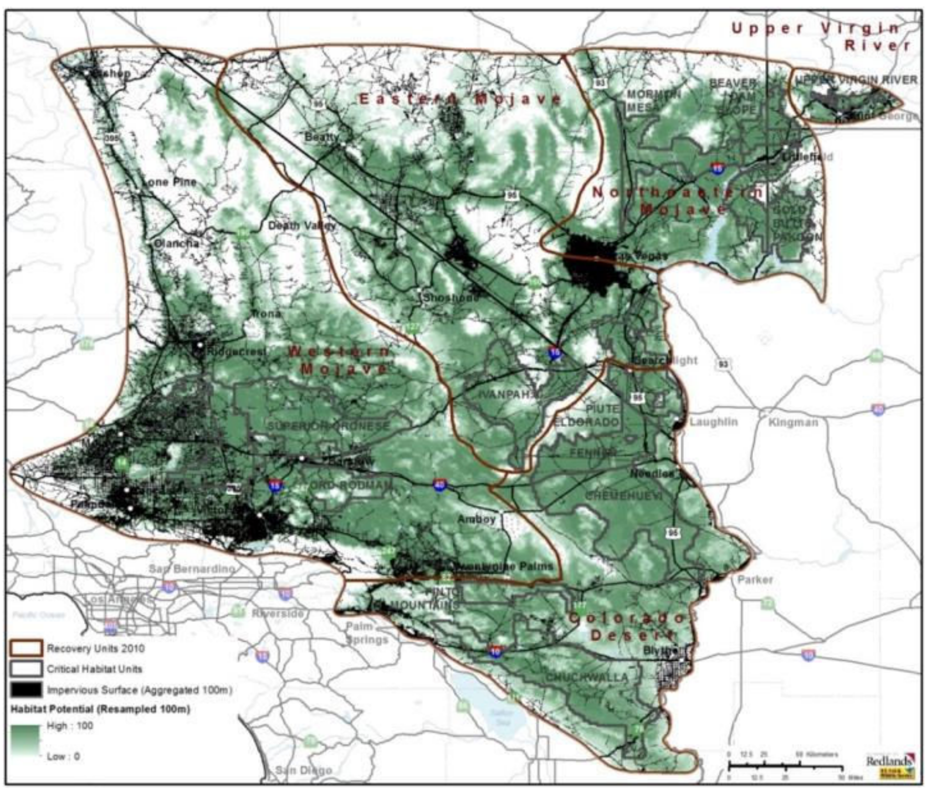


Figure 6. Probability of Presence Map Layer. The probability of presence surface is calculated by removing impervious surface from the USGS habitat potential surface.

We integrated this probability of presence surface into the main spatial calculations by multiplying all derived contribution to population change values at every point by the corresponding value of the probability of presence surface at that point, to arrive at the risk to the population at each point across the range of the tortoise (Figure 7).

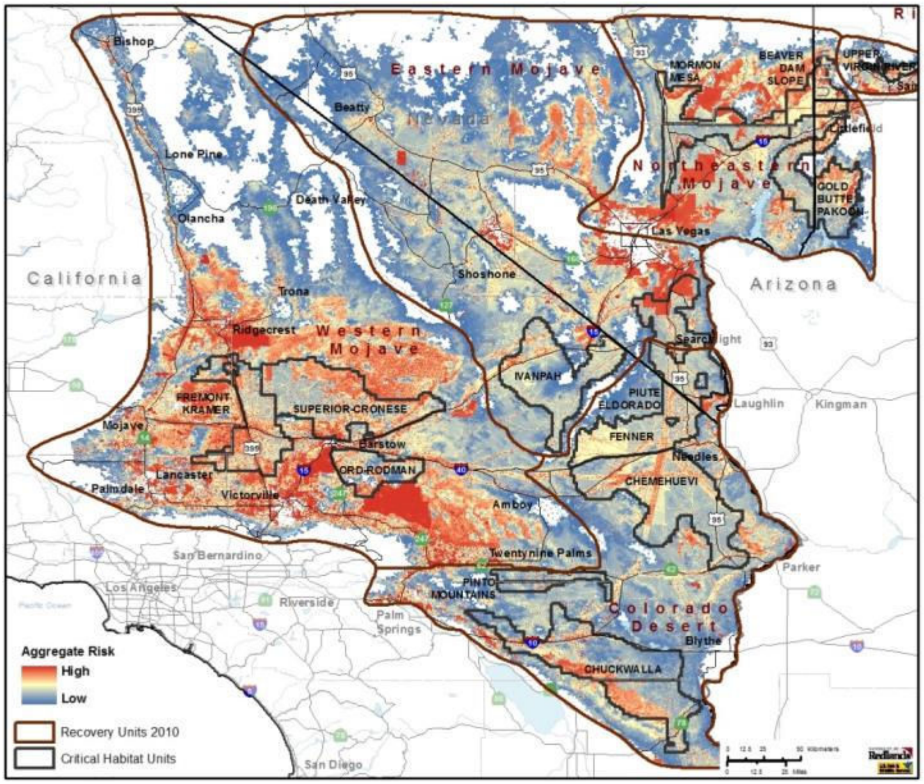


Figure 7. Risk to the tortoise calculated using the SDSS range-wide. Red is higher risk; blue is lower risk.

2.0 Estimation of decrease in risk to the tortoise resulting from potential recovery actions and associated variance

2.1 Conceptual Model

As described above, the SDSS conceptual model encapsulates scientific hypotheses about how the complex network of threats and recovery actions affect desert tortoise populations, as recorded in the revised Recovery Plan (USFWS 2011). We incorporated the 28 recovery actions recommended in the revised recovery plan for the Mojave desert tortoise into the SDSS model (USFWS 2011). The recovery actions are modeled as reducing the mechanism by which a threat affects the population (the threat-to-stress link in the model) (see Figure 1; Darst et al. 2013). In many cases, it is not the threat per se that can be ameliorated with a recovery action; rather, it is the stress caused by the threat. For example, tortoises are crushed by cars on paved roads. The threat is the cars; the effect of that threat, the stress, is tortoises being crushed. The recovery action of installing tortoise-exclusion fencing along the road does not reduce the threat (i.e., car traffic), but it does reduce the effect of the threat (i.e., tortoises being crushed by cars on the road).

The efficacy of each recovery action in suppressing the threat-stress mechanism was quantified as an effectiveness weight. An effectiveness weight of 1.0 between a recovery action and a particular threat-stress mechanism means that the recovery action would completely eliminate that mechanism where the recovery action was fully implemented (100 percent effective). A weight of 0.5 meant that the recovery action would only reduce that threat's intensity by 50 percent. We used expert assessment to estimate effectiveness of recovery actions on a 5-point scale, where 5 indicated the recovery action would fully ameliorate the stress caused by a threat and 0 meant the recovery action would have no effect. Because of the uncertainty around the effectiveness of many recovery actions for the desert tortoise (GAO 2002; Boarman and Kristan 2006; USFWS 2011), we estimated the predicted effectiveness of recovery actions at reducing each stress caused by a particular threat under two recovery action scenarios: best-case effectiveness (high-end) and worst-case effectiveness (low-end). We then calculated the average of these two values, and divided by 5 to express it as a percentage of the highest possible effectiveness score, which represents the overall recovery action effectiveness at reducing the effects of that threat. For example, an action with a high-end score of 5 and a low-end score of 2 would be given a predicted recovery action effectiveness score of (3.5/5) 9 100 = 70 % effectiveness at reducing the particular effects of the threat.

2.2 Spatial Computation of How a Recovery Action Reduces a Threat-Stress Mechanism

A recovery action is represented as a spatial data layer with implementation intensity values between 0 and 1 at every point, where 1 represents the recovery action being fully implemented, and 0 its absence, at the point. Each recovery action can have an ecological effects area that is specific to each threat-stress mechanism that the recovery action effects. For each threat-stress mechanism, we multiplied the intensity value of the ecological effects area for the threat-stress mechanism by the implementation intensity of the recovery action and its effectiveness weight to obtain the threat-stress mechanism reduction layer. Next we multiplied each threat-stress mechanism reduction layer value by the direct stress weight; and sum these values for all threat-stress mechanisms that the recovery action affects to produce the reduction in overall contribution to population change layer. For all recovery actions, we followed the guidance in the revised recovery plan for the tortoise (USFWS 2011) that recovery efforts should be first focused within designated tortoise conservation areas where we scored them as 100% effective at contributing to recovery, followed by actions within the identified linkages (Averill-Murray et al. 2013) where actions were scored as 75% effective at contributing to recovery, and then by tortoise habitat outside of these linkages where actions were scored as 10% effective at contributing to recovery. Finally, we multiplied that layer's value by the probability of presence to obtain the layer whose values are the reduction in risk to the population due to the recovery action (Figure 8).

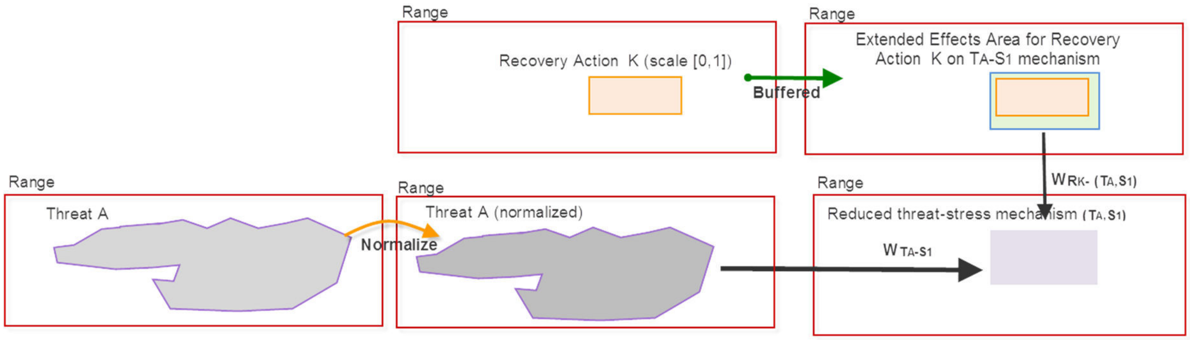


Figure 8. Calculation of reduction in threat-stress mechanism contribution due to a recovery action. The recovery action K acts on the threat-stress mechanism of threat TA contributing to stress S1 with an ecological effects area. The contribution of TA to S1 is reduced by the effectiveness weight WRK-(TA,S1) over the area of overlap between the ecological effects area and the original threat TA intensity footprint. Source: Murphy et al. 2013.

2.3 Calculation of Decrease in Risk due to Five Management Actions and Land Acquisition for the DRECP Acquisition-based Management Action mitigation ratios

To calculate acquisition-based mitigation ratios for the DRECP using the SDSS, members of the Renewable Energy Action Team (REAT) agencies determined a sub-set of recovery actions in the SDSS that may be appropriate for desert tortoise mitigation, in addition to habitat compensation in the form of land acquisition. We defined land acquisition as acquisition of tortoise habitat to facilitate recovery, focusing on particularly sensitive areas that would connect functional habitat or improve management capability of the surrounding area. The other management actions included: 1) installation and maintenance of fencing and signs around tortoise conservation areas marking boundaries of particularly sensitive or heavily impacted areas to regulate authorized use and discourage unauthorized use; 2) installation and maintenance of desert tortoise highway fencing to eliminate tortoise road mortality, with the installation of culverts to ensure connectivity where appropriate; 3) restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles; 4) relinquishment of grazing allotments within desert tortoise habitat; and 5) increase in law enforcement dedicated to reducing threats to the tortoise within Desert Wildlife Management Areas.

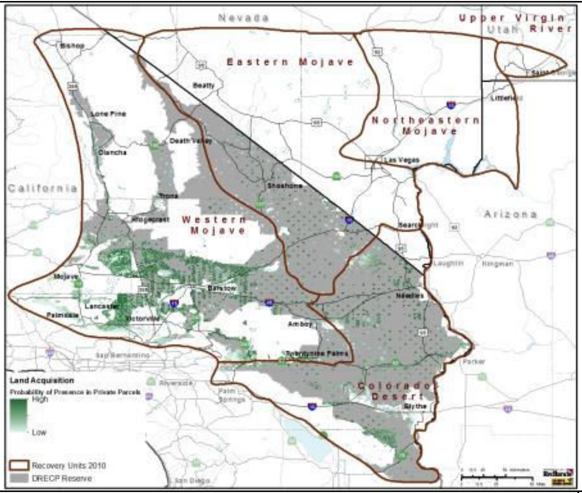
We created spatial footprints with ecological effects areas of each recovery action for all possible areas within which each action could take place in the Desert Renewable Energy Conservation Plan reserve lands (DRECP Preferred Alternative). Because mitigation for the desert tortoise should take place in the same recovery unit as the impact will occur, all analyses were conducted for each desert tortoise recovery unit in California (Table 1): 1) West Mojave Recovery Unit; 2) Colorado Desert Recovery Unit; and 3) a small piece of the East Mojave Recovery Unit (USFWS 2011). We modeled land acquisition as being able to take place on any private lands within the DRECP reserve (Figure 9a). We modeled signing and fencing protected areas as being able to take place around any Desert Wildlife

Management Area, Joshua Tree National Park, or Mojave National Preserve (Figure 9b). We modeled desert tortoise highway fencing as being able to be installed along any paved road within the reserve (Figure 9c). We modeled restoration of desert tortoise habitat as being able to take place on any closed grazing allotment, previously burned area, or any area damaged by motor vehicles off route within the reserve (Figure 9d). We modeled the relinquishment of grazing allotments as being able to occur for any open grazing allotment within the reserve (Figure 9e). We modeled an increase in law enforcement as being able to take place within any Desert Wildlife Management Areas within the reserve (Figure 9f).

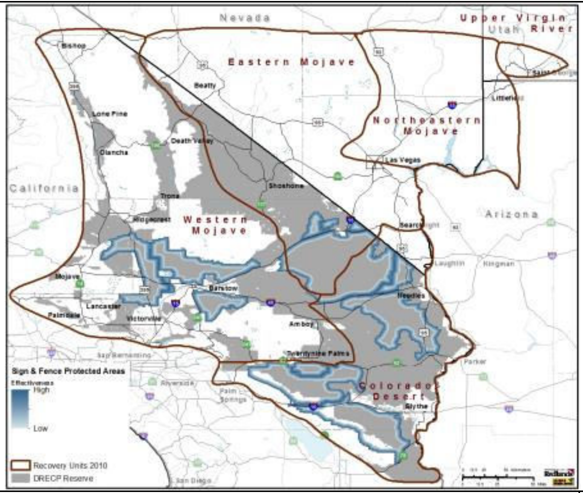
Table 1. Recovery action spatial footprints, ecological effects areas and intensity assignments

Recovery Action	Spatial Footprint	Ecological Effects Area	Intensity Scoring
Land acquisition of tortoise habitat to facilitate recovery, focusing on particularly sensitive areas that would connect functional habitat or improve management capability of the surrounding area	Any privately o held lands within the DRECP reserve area (2013 BLM landownership: 'Unclassified' parcels)	N/A	100% where lands area acquired
Installation and maintenance of fencing and signs around tortoise conservation areas marking boundaries of particularly sensitive or heavily impacted areas	Around any Desert Wildlife Management Area, Joshua Tree National Park, or Mojave National Preserve	Graduated linear buffer 3.1-miles inside the signed and fenced tortoise conservation area	100% where fencing and signing is installed
Installation and maintenance of desert tortoise highway fencing with culverts where appropriate	Along either side of any paved road within the DRECP reserve area	Graduated linear buffer 1-mile out from the side of the road that is fenced	100% where fencing is installed
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Within any closed grazing allotment, previously burned area, or any area damaged by motor vehicles off route within the DRECP reserve area	N/A	100% where restoration is conducted
Relinquishment of grazing allotments within desert tortoise habitat	Any open grazing allotment within the DRECP reserve area	N/A	100% where grazing is relinquished
Increase in law enforcement dedicated to reducing threats to the tortoise within Desert Wildlife Management Areas	Within any Desert Wildlife Management Areas within the DRECP reserve area	N/A	100% for 2 rangers in 247,105-acre area

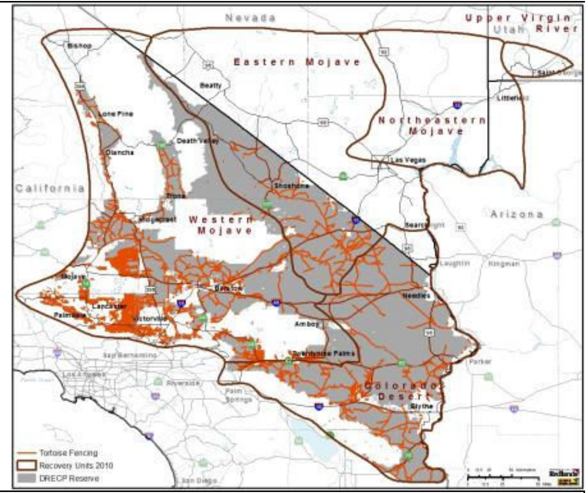
We calculated the average decrease in risk for each action inside the DRECP reserve for each desert tortoise recovery unit in California. We calculated Delta Risk = total amount of population risk reduced by doing the particular recovery action in each recovery unit as described in Section 3.1.1 (Tables 2-5). We then divided the decrease in risk for each action by the area or length of the entire potential action (RATotal = total number of units of the action, acres or miles, that were modeled in each recovery unit) to determine the decrease in risk per RA unit (acres or miles). We calculated Unit/MDeltaRisk = RATotal/(DeltaRisk/1,000,000) to represent the number of RA units (acres or miles) required to produce a reduction of 1 million units of population risk. We then used Land Acquisition as our reference so that all the other ratios were compared against 100-acres of Land Acquisition by dividing each recovery action's Units/MDeltaRisk by Land Acquisition's Units/MDeltaRisk (Table 2-4). In a similar manner, to estimate the ratio of the benefit of an increase in law enforcement for each Desert Wildlife Management Area, we calculated how many 100-acre parcel acquisitions would be needed within each recovery unit to get the same risk in reduction of placing one additional law enforcement officer in each DWMA (Table 5).



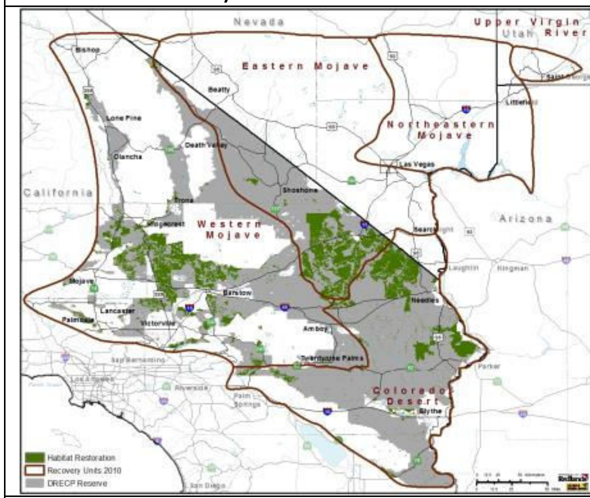
9a. Land acquisition of tortoise habitat to facilitate recovery



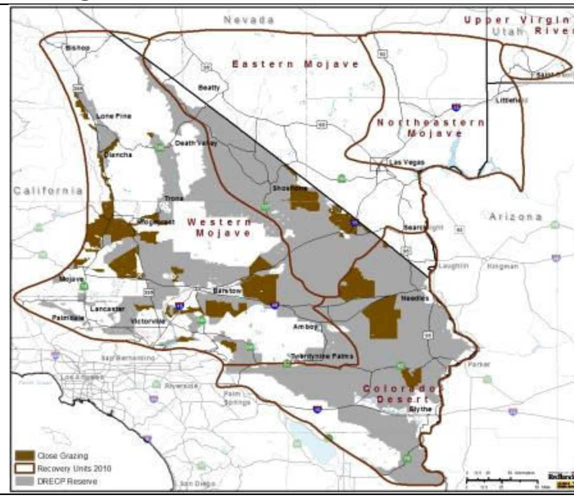
9b. Installation and maintenance of fencing and signs around tortoise conservation areas



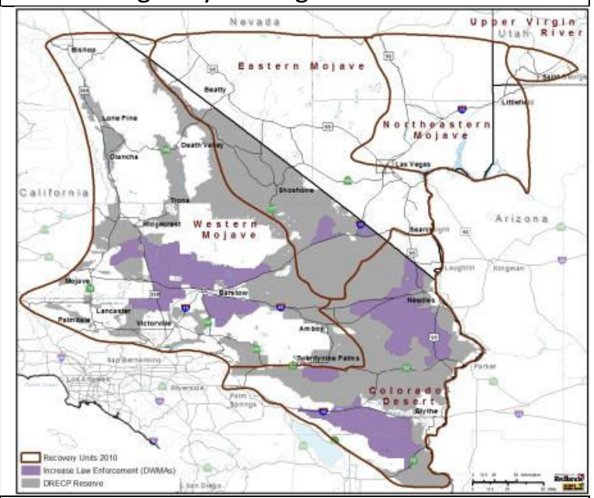
9c. Installation and maintenance of desert tortoise highway fencing



9d. Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles



9c. Relinquishment of grazing allotments within desert tortoise habitat



9d. Increase in law enforcement dedicated to reducing threats to the tortoise within Desert Wildlife Management Areas

Figure 9. Spatial footprints with ecological effects areas of each recovery action for all possible areas within which each action could take place in the Desert Renewable Energy Conservation Plan reserve lands (DRECP Preferred Alternative).

Table 2. West Mojave Recovery Unit Ratios

Recovery Action	Unit	RA Total Units	Delta Risk	Ratio to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	656	232,336,857	1
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	6,311	257,059,307	10
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	1,231,732	1,296,786,654	949
Relinquishment of grazing allotments within desert tortoise habitat	Acres	1,051,590	779,704,119	560
Land acquisition	Acres	1,023,805	4,249,210,383	100

Table 3. Eastern Mojave Recovery Unit Ratios

Recovery Action	Unit	RA Total Units	Delta Risk	Ratio to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	242	66,078,904	3
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	1,204	121,638,813	7
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	1,016,832	919,508,064	798
Relinquishment of grazing allotments within desert tortoise habitat	Acres	265,710	289,616,701	662
Land acquisition	Acres	33,473	241,521,095	100

Table 4. Colorado Desert Recovery Unit Ratios

Recovery Action	Unit	RA Total Units	Delta Risk	Ratio to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	1,070	99,447,014	3
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	2,371	266,647,143	2
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	904,493	651,647,866	335
Relinquishment of grazing allotments within desert tortoise habitat	Acres	569,481	1,140,084,546	121
Land acquisition	Acres	266,149	642,073,298	100

Table 5. Ratios for Increase in Law Enforcement

Desert Wildlife Management Area	Recovery Unit	DWMA Area (acres)	Delta Risk of 1 LEO	# of 100-acre land acquisitions = 1 additional LEO
Fremont-Kramer	West Mojave	429,031	72,616,627	175
Superior-Cronese	West Mojave	596,637	58,956,097	142
Ord-Rodman	West Mojave	246,208	51,475,956	124
Ivanpah	Eastern Mojave	34,933	63,572,607	88
Shadow Valley	Eastern Mojave	91,204	60,240,909	83
Piute-Fenner	Colorado Desert	164,804	46,687,012	194
Pinto Mountains	Colorado Desert	114,400	40,209,177	167
Chemehuevi	Colorado Desert	858,351	41,495,051	172
Chuckwalla	Colorado Desert	503,558	34,156,019	142

2.4 Analysis of Variance in Decrease in Risk for DRECP Actions

The ratios recorded in Tables 2-5 above are the output of a complex spatial decision support system. As such, there are uncertainties associated with those values that are inherent to such systems, such as uncertainty in the spatial threats data, in the expert weights, and in the structure and form of the modeling (Gottsegen et al. 1999). While we have an ongoing research project to characterize those data and system uncertainties, the uncertainty in the above ratios is dominated by the spatial variation in each recovery action's effectiveness. The overall numbers we presented in Tables 2-5 for the relative effectiveness of recovery actions were *averages* over each recovery unit. This average comes from effectiveness values of places where implementing a recovery action is very beneficial to the tortoise and places where implementing the recovery action would be much less beneficial (Figure 10). For example, installing 10 miles of tortoise fencing along a paved road where there are few tortoises compared to installing 10 miles of fencing along a road in high quality habitat produces decreases in risk that differ by 2 orders of magnitude. The relative effectiveness ratio between the most effective areas and the least effective areas for land acquisition is almost 190. Comparing a recovery action implemented in the least effective areas against land acquisition executed in the most effective areas produces relative ratios that can climb to 4 orders of magnitude in difference.

In our analyses of variance, we assumed that resource managers will tend, cost considerations aside, to design specific projects at sites where they will be most effective. In addition, once they have exhausted the most effective areas for a particular recovery action in a recovery unit, they would likely, if relative effectiveness are known, move on to the next most effective recovery action locations. Accordingly, for each recovery action, we divided the 100-m^2 cells where each action could be implemented in the DRECP reserve area into 10% percentile bins. Below the 50%-59% percentile, the effectiveness of many recovery actions decreases dramatically. Therefore, we assumed that recovery actions would not be implemented below the 50th percentile, which is equivalent to assuming that recovery actions are implemented in at most the top 50% of the potential locations. We then took the ratios of the effectiveness of the other five recovery actions against land acquisition in each percentile range, and recorded the minimum and maximum values as the expected variance for each ratio, within each recovery unit (Tables 6-8). The variation related to designing where to increase law enforcement is different, since law enforcement officers are assigned to entire DWMAs. Thus, a reasonable characterization of the variance in potential effectiveness for increasing law enforcement within each recovery unit is simply the variation between or among DWMAs (Table 9).

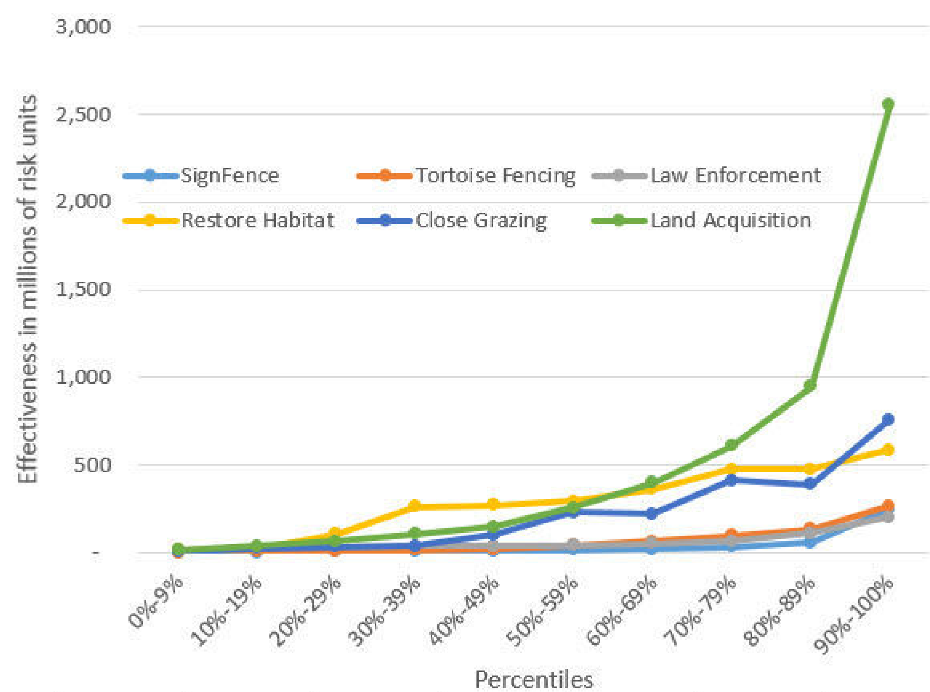


Figure 10. Effectiveness of recovery actions in millions of risk units. The 100-m^2 area cells where a recovery action can be implemented are ordered by the effectiveness of that recovery action in reducing population risk when implemented in each cell. The cells are then grouped into percentile ranges and the total risk reduction for each percentile is shown.

Table 6. West Mojave Recovery Unit: Variance in Ratios of Effectiveness of Recovery Actions compared to Land Acquisition

Recovery Action	Unit	Ratio to Land Acquisition	Variance in Ratios to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	1	(1–3)
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	10	(9– 17)
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	395	(246– 997)
Relinquishment of grazing allotments within desert tortoise habitat	Acres	560	(510– 977)
Land acquisition	Acres	100	--

Table 7. Eastern Mojave Recovery Unit: Variance in Ratios of Effectiveness of Recovery Actions compared to Land Acquisition

Recovery Action	Unit	Ratio to Land Acquisition	Variance in Ratios to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	3	(1–5)
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	7	(3– 13)
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	798	(243– 2381)
Relinquishment of grazing allotments within desert tortoise habitat	Acres	662	(216– 1361)
Land acquisition	Acres	100	--

Table 8. Colorado Desert Recovery Unit: Variance in Ratios of Effectiveness of Recovery Actions compared to Land Acquisition

Recovery Action	Unit	Ratio to Land Acquisition	Variance in Ratios to Land Acquisition
Installation and maintenance of *fencing and signs around tortoise conservation areas* marking boundaries of particularly sensitive or heavily impacted areas	Miles	3	(1–4)
Installation and maintenance of *desert tortoise highway fencing* with culverts where appropriate	Miles	2	(1– 3)
Restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles	Acres	335	(116– 1029)
Relinquishment of grazing allotments within desert tortoise habitat	Acres	121	(67– 473)
Land acquisition	Acres	100	--

Table 9. Variance in Ratios of Effectiveness of Increasing Law Enforcement compared to Land Acquisition

Recovery Unit	DWMA Area (acres)	# of 100-acre land acquisitions = 1 additional LEO
West Mojave	1,271,876	124-175
Eastern Mojave	126,137	83-88
Colorado Desert	1,641,113	142-194

3.0 Conclusions

The Desert Tortoise SDSS can calculate the potential benefit to the tortoise from many different kinds of recovery actions all on the same scale, decrease in risk, such that comparisons across management actions for mitigation ratios can be made. The main assumptions of the overall SDSS have been well-documented (please see Murphy et al. 2013). For each desert tortoise recovery unit in California, we calculated the average decrease in risk for six recovery actions: 1) acquisition of tortoise habitat to facilitate recovery, focusing on particularly sensitive areas that would connect functional habitat or improve management capability of the surrounding area; 2) installation and maintenance of fencing and signs around tortoise conservation areas marking boundaries of particularly sensitive or heavily impacted areas to regulate authorized use and discourage unauthorized use; 3) installation and maintenance of desert tortoise highway fencing to eliminate tortoise road mortality, with the installation of culverts to ensure connectivity where appropriate; 4) restoration of desert tortoise habitat in areas previously damaged by grazing, fire, or off-highway vehicles; 5) relinquishment of grazing allotments within desert tortoise habitat; and 6) increase in law enforcement dedicated to reducing threats to the tortoise within Desert Wildlife Management Areas. We then compared across these averages to determine the amount (acres or miles) of actions 2 through 6 necessary, on average, to equal 100-acres of land acquisition in the West Mojave, Eastern Mojave, and Colorado Desert recovery units.

The differences seen among the decreases in risk per RA unit from an action in one recovery unit to another recovery unit result from the size of the recovery unit itself, since this affects statistical sampling, and the existing threats (baseline risk) in each unit. First, only a small portion of the Eastern Mojave recovery unit occurs in California (Figure 6) and the two DWMAs within that recovery unit are also very small (Figure 9a & 9f). Therefore, the total acres or miles that could be modeled for each action in the Eastern Mojave recovery unit were much smaller than in either the Western Mojave or Colorado Desert, often resulting in a greater decrease in risk per unit (area or length) for actions in the Eastern Mojave, particularly land acquisition. Second, the baseline risk influenced the potential decrease in risk which could occur from actions modeled in each recovery unit. For example, there is more private land within important desert tortoise habitat with a risk of being converted to development in the

Western Mojave than in the Colorado Desert recovery unit resulting in a greater decrease in risk per acre for land acquisition. Also, there is greater human access in the Western Mojave recovery unit than in either the Eastern Mojave or Colorado Desert, such that there is more baseline risk to decrease when signing and fencing is installed around DWMAs. The Colorado Desert has more acres of open and active grazing allotments within important desert tortoise habitat, and therefore relinquishment of grazing produces a large decrease in risk to the tortoise in this recovery unit. Both the Colorado Desert and Eastern Mojave have fewer miles of paved roads than the Western Mojave, however because the paved roads in the Eastern Mojave and Colorado Desert tend to go through higher probability of tortoise presence areas than in the Western Mojave, the average benefit to the tortoise per mile of fence is greater in the Eastern Mojave and Colorado Desert than it is in the Western Mojave.

Depending on where on the landscape a specific recovery action is implemented, its effectiveness in reducing population risk to the desert tortoise will vary significantly. The numbers we presented in Tables 2-5 for the relative effectiveness of recovery actions compared to 100 acres of land acquisition were averages over each recovery unit. There are places across the landscape where implementing a recovery action is very beneficial to the tortoise and there are areas where implementing the recovery action would be much less beneficial. While it may not be possible to design 5 continuous miles of tortoise fencing where all miles effected fall into the very top effectiveness percentile range for tortoise fencing, managers should look to locate specific projects in areas with highest possible effectiveness, and costs permitting, move to other recovery actions once the most effective areas for a particular recovery action have been exhausted. The actual relative effectiveness ratio between any two specific recovery action implementations will vary accordingly, and we anticipate the variance to be within the range presented in Tables 6-9.

Our approach provides an objective process for quantifying threats and estimating the benefit of conservation actions for any at-risk species. This approach requires: 1) a conceptual model of how threats affect the species (or group of species) of interest; 2) empirical data or expert assessment of the relative contribution of threats to population change; 3) a set of conservation actions and an estimation of their effectiveness at affecting links in the conceptual model; 4) spatial datasets to represent threats and potential actions; and 5) a range, habitat, or population density map. We have designed a process for building and quantifying the conceptual model and have developed an application that manages the conceptual model and all supporting information to calculate threat severity and potential benefits of recovery actions. Although we developed this approach for the threatened Mojave desert tortoise, it is a process that can be valuable for threats assessment and conservation planning for other at-risk species, and it can be readily employed even in situations for which very little data exist on the effects of threats on a species such that action prioritization can be easily updated in an adaptive management framework as new information becomes available.

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APPENDIX C:
Additional Details on Desert Tortoise SDSS Improvements

This appendix provides more detail on data and system improvements to the Desert Tortoise Spatial Decision Support System (SDSS), mentioned in **Chapter 6: Improving Workflow and Usability of the System.**

C.1 Data Management and Updates

The spatial datasets in the Desert Tortoise SDSS are central to system calculations, defining in geographic space where threats exist and to what degree that threat location contributes to tortoise population decline. These spatial data also define the location of potential recovery actions, and provide baseline geological and ecological data. Appendix A provides a complete inventory of data in the Desert Tortoise SDSS.

C.1.1 Data Acquisition and Creation

New base spatial datasets offer the opportunity for iterative improvement. Imagery can be updated, new spatial data can be collected, or existing linework can be improved. During this project, the National Landcover Database (NLCD) released landcover datasets for 2011 imagery, which update their datasets from 2006 imagery. Several important layers within the SDSS use NLCD datasets, including threat layers such as development and agriculture. The NLCD's impervious surfaces dataset is also used, along with the USGS desert tortoise habitat potential model (Nussear et al. 2009), to create the *probability of presence* layer (Murphy et al. 2013).

The updated NLCD data was used to create a new baseline risk layer representing risk to the tortoise from existing threats. The project team then examined how this new baseline risk layer affected impact and mitigation calculations for the three study solar energy development projects and their associated mitigation packages. Given that the team already possessed the site and mitigation data from the 2011 proposal for the Ivanpah Solar Electricity Generation System (ISEGS), this involved collecting spatial data representing the footprint, ancillary construction, and recovery action locations for the Blythe and Genesis solar sites. Site data was also gathered for an additional two proposed projects, the Silver State and Stateline solar sites for study of their potential impacts on population fragmentation in the Ivanpah Valley. Other base, threat, and recovery action data were updated as well (Table C.1 summarizes major updates and additions).

Table C.1: Summary of Major Updates and Additions to System Data

Type of Data	Action Taken	Related Datasets
Threats	Updated Data	OHV line work; Potential Conversion - Private & State Parcels; aqueducts and canals; USGS Mineral Locations Database; SW Grazing
Threats	New Data	So Cal Gas pipeline; Wind Farm data from USGS; NOAA Drought Outlook in the SW US
Recovery Actions	Updated Data	Tortoise barrier fencing
Baseline Data	Updated Data	CA Ownership; CA BLM Acquisition parcels; revised Solar Energy Zones from PEIS
Baseline Data	Removed	CA Indian Reservations (included in new BLM ownership dataset)

Source: Desert Tortoise SDSS

C.1.2 Data Curation and Review

All datasets, both those used and integrated within the SDSS and those evaluated but not used, have been cataloged in a data inventory with the threat or recovery action type, description, data source and URL, year, status, map and model notes, and any selection or filter criteria identified.

For each dataset detailed metadata and a map image are provided for system users. For this project, the team adopted a new naming convention and archiving system which allows for faster web mapping and preserves all original source data on the network. The project partners also developed templates to quickly evaluate the status of various threats or recovery actions and to convey this information graphically in reports and public outreach efforts.

The data inventory system is in Microsoft® SharePoint online and catalogs the data resources, with hyperlinks to the metadata, map images, and data layer packages posted to the Web server. Current spatial data holdings include 339 threat layers, 159 of which are used in the system and data sets of 42 already implemented recovery actions, 33 of which are being used. The inventory also includes 195 base data layers that may be used by the system's various components for informational purposes but are not used explicitly for modeling (e.g., landscape features and landmarks, jurisdictional boundaries, habitat resources). In a separate database there are 92 datasets related to solar energy development footprints, additional construction features, and the proposed action in mitigation packages. 57 of these datasets are made available for solar energy development impact calculations.

The spatial datasets themselves are stored in a Microsoft SQL Server database using Esri's ArcGIS Server Enterprise Advanced® and managed using Esri's ArcGIS Desktop® suite of products. For each dataset that is used by the Desert Tortoise SDSS, detailed metadata, and a map image are provided for system users. The project team adopted a naming convention which indicates the spatial extent of the data (e.g., CA_, MOJ_, SW_) and maintains two identical versions in two coordinated systems. One is WGS_1984_Web_Mercator_Auxiliary_Sphere which allows for faster web mapping and the other database is USA_Contiguous_Albers_Equal_Area_Conic which preserves the geometry in an equal area projection and is used for spatial analysis. All original source data is archived.

C.1.3 Metadata Development

For all input data sets to the Desert Tortoise SDSS, the project team performed a complete review of source notes and processing steps and recorded these as standard ArcGIS and FGDC metadata. The FGDC metadata HTML export was then attached to the data inventory system and published to the updated Data Explorer application. The Summary version of the metadata previously produced, as well as the text version of the FGDC metadata, were removed after being determined to be both redundant and time consuming. The metadata files are included in every zipped shapefile and layer package available for download from the Data Explorer.

The map services, map documents, and layers packages on the Data Explorer website now have standardized metadata descriptions. This information includes a summary and a full description of what the map represents, keywords for searching, access constraints, and data sources.

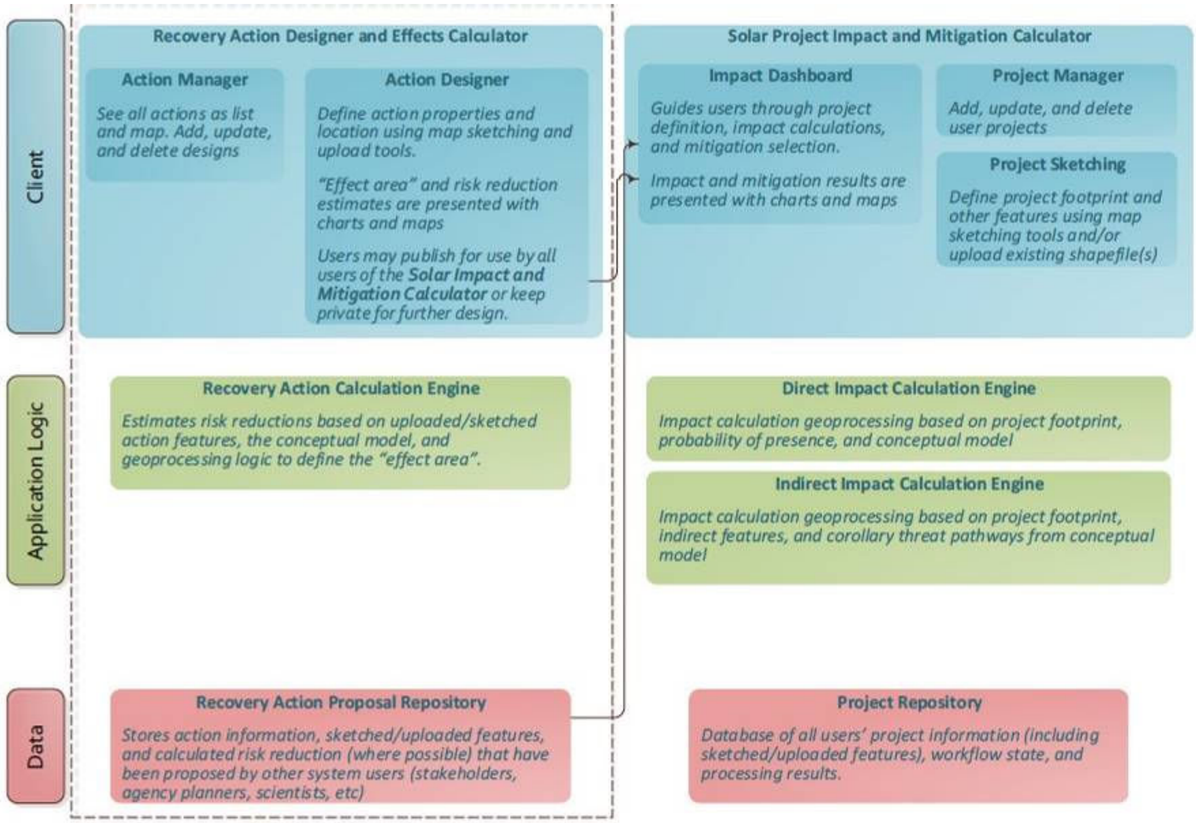
C.1.4 Map Templates and Cartography

A number of ArcMap templates were developed to allow the team to quickly evaluate the status of various threats or recovery actions and to convey this information graphically in reports and public outreach efforts. Standard symbology stored as ArcMap symbology style files (.style) allows for easy modifications as data are updated. These map templates were used to render maps in the report template interface design of the Solar Projects Impacts and Mitigation Calculator (described in Chapter 6, Section 6.1.2).

C.2 Revised Architecture for the Desert Tortoise Recovery Portal

Figure 6.3 in Section 6.2 (included here as Figure C.1) visually illustrates revisions to the system architecture completed during this project, including addition of the recovery action database and related tools (Recovery Action Designer and Tracking tool) in order to make recovery actions available and calculable for inclusion in mitigation packages. This section describes these architectural elements in greater detail.

Figure C.1: Architecture of the Revised Desert Tortoise Recovery Portal



An illustration of the architecture for the expanded Desert Tortoise Recovery Portal. The dotted silo represents the components added as part of this project.

Source: Desert Tortoise Recovery Portal

C.2.1 Client Tier

C.2.1.1 Recovery Action Designer

This tool is the primary interface for users to define their recovery/mitigation actions. As described in Sections 2.4 and 6.1.1, a number of properties must be provided to both 1) uniquely identify and describe the project; and 2) enable the calculation engine to better estimate the effect based on the conceptual model. Once the site-specific action is designed, the calculation engine estimates the estimated effectiveness of this action, which is displayed along with auto-generated maps and charts. Based on these results, the user can decide to modify the design or publish the design to the Recovery Action Proposal Repository for review and selection by themselves or other users.

C.2.1.2 Action Manager

The Recovery Action Manager is the interface for an individual user to access all of their actions as a list. This is also the interface to start a new action, update an existing action, or delete an action.

C.2.2 Application Logic Tier—Recovery Action Calculation Engine

The calculation engine is the processing component that estimates risk reductions based on submitted recovery actions. It takes the action information and sketched or uploaded features as input from the Recovery Action Designer, and executes the workflow that calculates risk reductions using Esri's ArcGIS Server geoprocessing services. The calculated values are stored with the recovery action, and referenced according to the version of the SDSS used for that calculation. While the processing workflows and automation scripts for this calculation have been in place and used by the project team since 2012, this new engine brings the results directly to the users who are designing recovery actions.

C.2.3 Data Tier

C.2.3.1 Recovery Action Proposal Repository

The database of recovery action proposals was expanded to support the designs captured using the Recovery Action Designer as described above. The SDSS database previously managed recovery action names, descriptions, and the calculated effectiveness score as presented in the Solar Project Impact and Mitigation Calculator. The project team expanded this database to include the detailed action properties and map features submitted by users, as well as the detailed results of the calculation engine, including maps and the threat reduction breakdown.

C.2.3.2 Scenario Manager

An important backend component of the system architecture developed as part of this project is the Scenario Manager. With each iteration of system development, the conceptual models, the input data sets (threats, recovery actions, probability of presence, etc.) and the SDSS calculation engine have been improved. Each run of the SDSS engine results in a large collection of statistical and spatial data outputs. In order for calculations from previous iterations to be repeated in later iterations for verification and comparison, the project partners introduced the concept of a Scenario. A Scenario is collection of all of the inputs and outputs of a full SDSS engine calculation run along with identifying information about the run.

The primary inputs to the system are: (1) threat intensity grids and (2) the conceptual model (.tcm) defining the entities (threats, stresses, population effects, recovery actions) and their relationships and weights. The primary outputs of the system are: (1) population stress rasters (spatial normalization and any threat-stress spatial operations applied), (2) a wealth of statistics for all entities within the conceptual model broken down by tortoise conservation areas and other common reporting units, and (3) spatial risk raster depicting the spatial distribution of risk across the range. By storing and tracking all of the data related to a Scenario, the project team can review or repeat a calculation for further investigation. This concept has been integrated across the system to relate analysis products (statistics, maps, charts, etc.) to the Scenario that they were based on.

C.3 Example Workflows for Desert Tortoise Recovery Portal

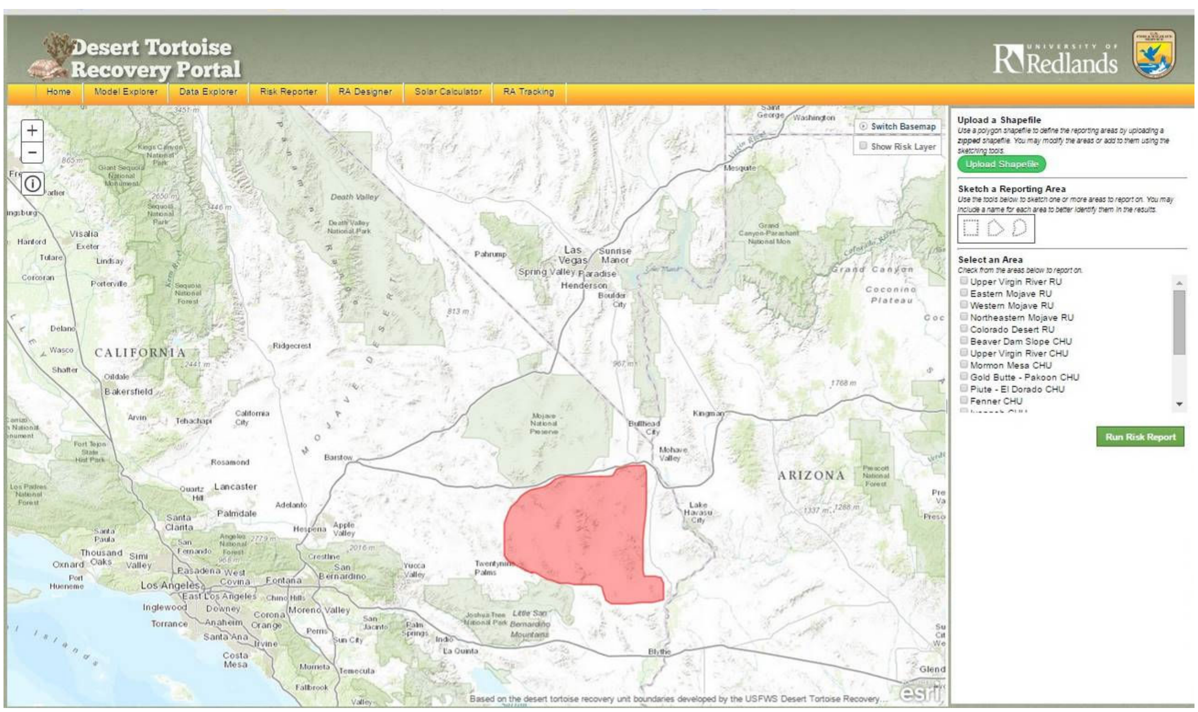
Section 6.1.3 describes five different user workflows (use cases) for using the Desert Tortoise Recovery Portal. In Section 6.3, the first user workflow (Project Designer or Reviewer) is described in detail. This section provides additional detail on how other users might employ the Portal in their workflow.

C.3.1 Second workflow: Land or wildlife manager, scientist or stakeholder

Through the map interface and dashboards of the Risk Reporter tool, this user group can explore the spatial nature of current risks to the population and how recovery actions included in a proposed project mitigation package may affect these risks. This user could employ the new Risk Reporter tool to investigate which threats, stresses, and population effects are contributing to risk within a particular area, and evaluate the appropriateness and effectiveness of proposed recovery actions placed on the landscape.

From the map in the Risk Reporter, a user employs the dashboard tools to define the area within the desert tortoise range for calculating risk estimates in one of three ways: (1) by uploading a shapefile, (2) by drawing a polygon with sketching tools, or (3) by selecting a pre-defined area such as a tortoise conservation area or critical habitat unit (Figure C.2).

Figure C.2: Risk Reporter Tool Interface: Defining an Area of Interest

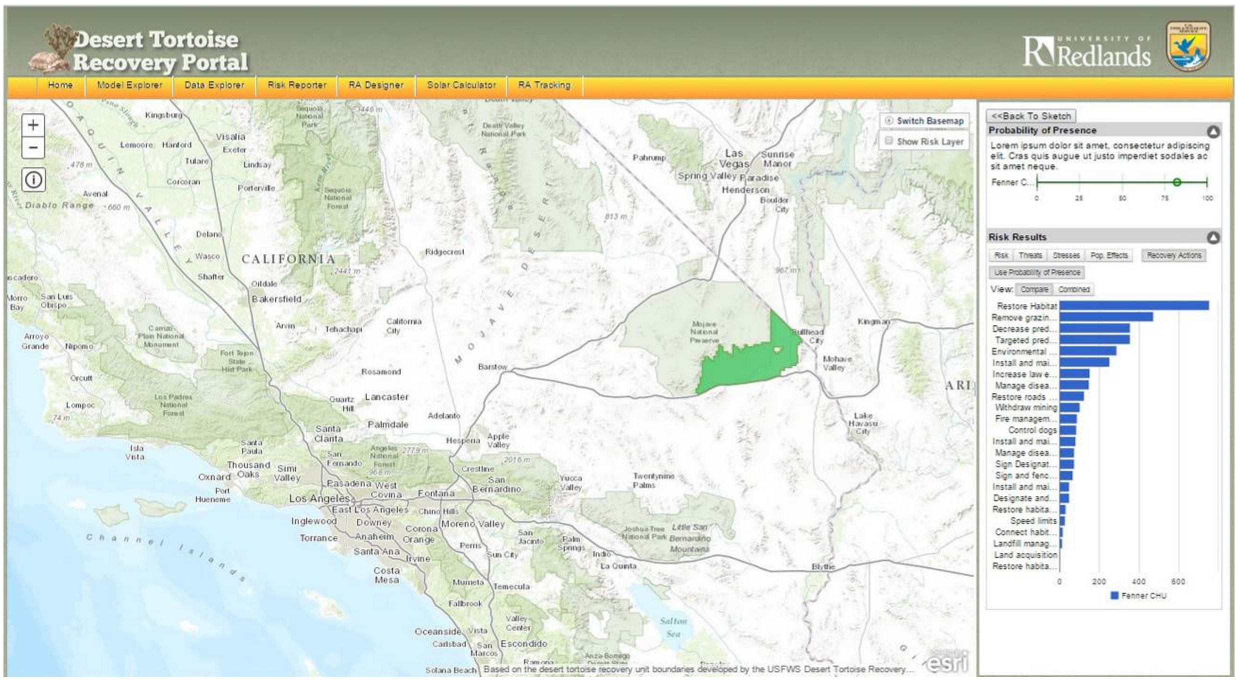


In the Risk Reporter tool, the user defines the area for calculating risk estimates either by uploading an existing shapefile (e.g., project footprint), sketching an area, or selecting a pre-defined area such as a critical habitat unit. In this example, the user has drawn a polygon for which risk estimates will be calculated.

Source: Desert Tortoise Recovery Portal

Once an area is defined in the Risk Reporter tool, the user can calculate risk estimates. Results display in the right-hand dashboard panel and include estimates related to: (a) the relative *probability of presence* for the desert tortoise presence, (b) aggregate risks –overall, or broken out by contributing threats, stresses affected, and population effects, and (c) potential effectiveness of recovery actions types for that area (Figure C.3). All the analysis in (b) and (c) can be performed with our without applying the probability of presence to the aggregate risk results.

Figure C.3: Risk Reporter Online Tool: Results Dashboard



Once an area is defined and risks calculated, the results display in the right-hand dashboard panel of the Risk Reporter. In this case, the results are being calculated for an existing defined area, the Fenner Critical Habitat Unit.

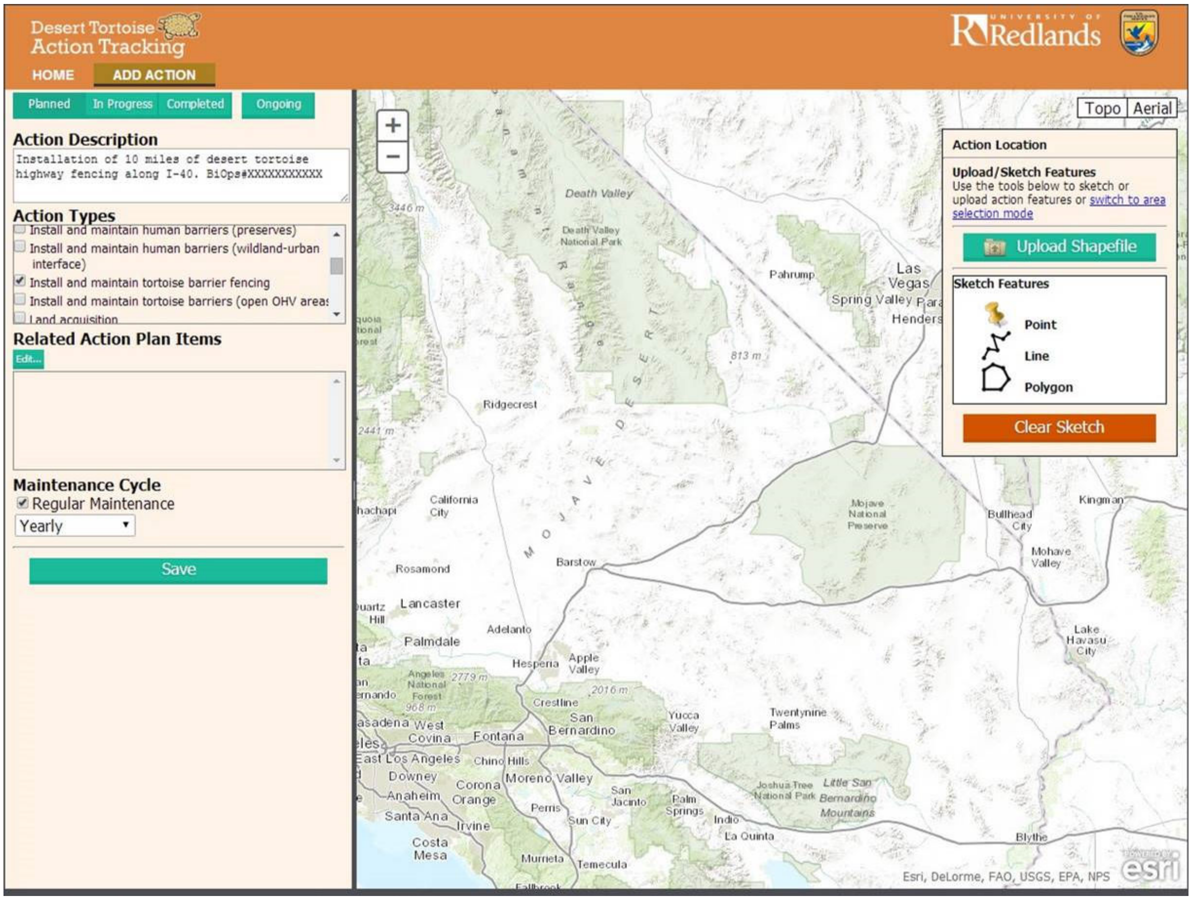
Source: Desert Tortoise Recovery Portal

C.3.2 Third Workflow: Land Managers

A land manager uses the Recovery Action Tracking tool (Section 2.3; Figure 2.4) to add descriptions, locations, and extents of recovery actions being implemented on the ground. These can then be compared with the proposed area and location as designed in the original mitigation package to monitor whether or not proposed mitigation was completed.

The "Add Action" tab in the Tracking tool takes the user to the Recovery Action Designer (Section 2.3; Figure 2.5), which provides a map application, a dashboard for sketching or uploading a shapefile of the geographic location(s) of the recovery action, and a dashboard for describing the recovery action type and its relation to the desert tortoise Recovery Action Plan. First, the user describes the action to be taken, and selects which recovery action type it represents (Figure C.4). In this example, the user is entering into the tool where they have installed 10 miles of desert tortoise fencing along a major highway, which is part of the recovery action type "Install and maintain tortoise barrier fencing".

Figure C.4: Defining Specific Recovery Actions using the Recovery Action Tracking Tool: (1) Describing Action and Selecting Action Type

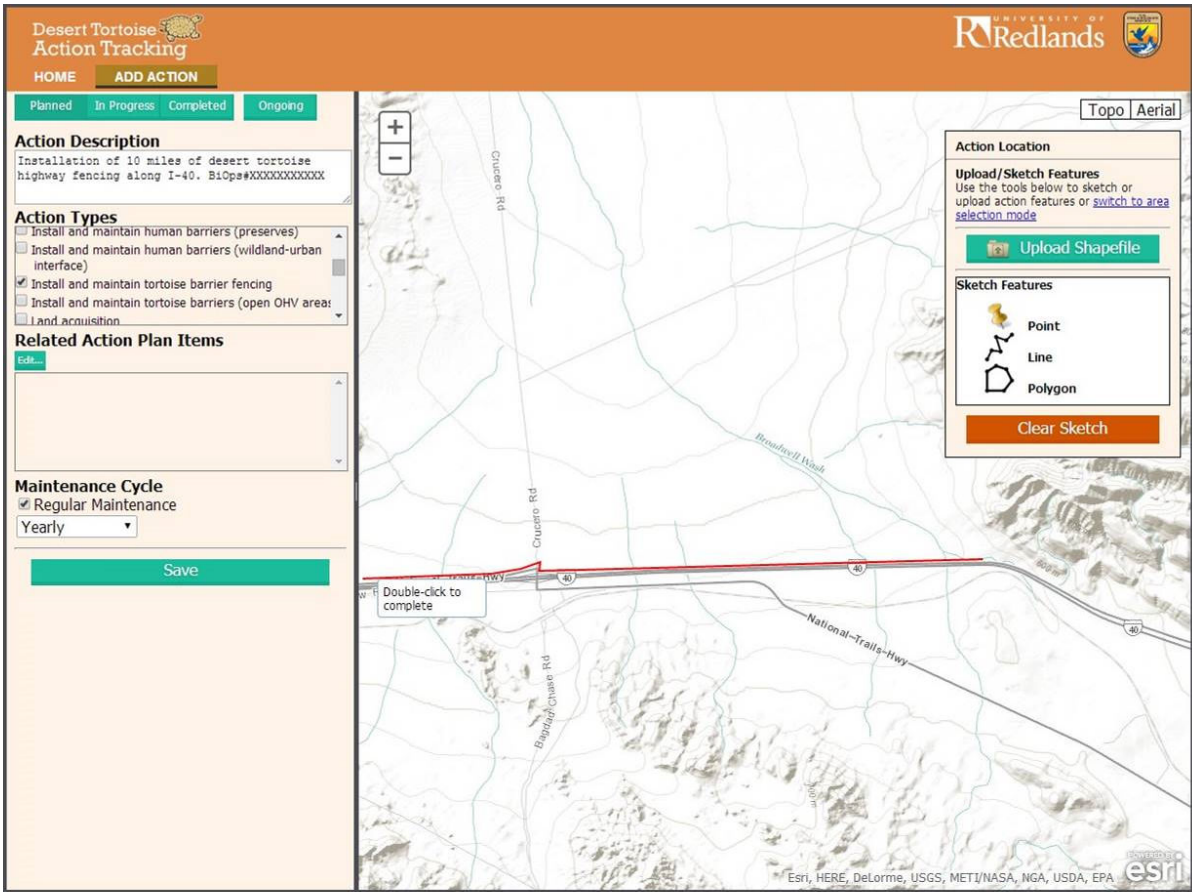


The first step in designing a recovery action is to describe the action and select which recovery action type it represents. In this example, the user proposes to install 10 miles of desert tortoise fencing along a major highway, which is part of the recovery action type "Install and maintain tortoise barrier fencing".

Source: Desert Tortoise Action Tracking Tool, Desert Tortoise Recovery Portal

Next, users locate where the action has been completed or will be undertaken, by either uploading a shapefile, selecting a pre-defined area, or sketching on the map interface (Figure C.5). In this example, the user has chosen to sketch where the highway fencing will be placed (red line). Notes can be added to further describe the sketched feature: in this case the fencing will be placed on the westbound side of the highway. Users can also specify a timeframe for maintenance of a designed recovery action: in this example, the fence is to be maintained yearly.

Figure C.5: Defining Specific Recovery Actions using the Recovery Action Tracking Tool: (2) Spatial Location and Timeframe of Recovery Action



The second step in designing a recovery action is to specify the spatial location of the action. Users can upload or sketch features. In this example, the user has sketched where the highway fencing will be placed (red line), and specified yearly maintenance.

Source: Desert Tortoise Action Tracking Tool, Desert Tortoise Recovery Portal

Once designed the recovery action is saved to the database and becomes available to other users for inclusion in mitigation packages. Information about the creation date, user, recovery action type, and other user-specified information can be reviewed through an Action Details page (Figure C.6).

Figure C.6: Defining Specific Recovery Actions using the Recovery Action Tracking Tool: (3) Recovery Action Details

Designed recovery actions are saved to the database of the Desert Tortoise SDSS and are then available for selection by other users. Details such as the creator, recovery action type, and date last updated are provided on this Recovery Action Details page.

Source: Desert Tortoise Action Tracking Tool, Desert Tortoise Recovery Portal

C.3.3 Fourth Workflow: Project Team System Maintenance and Data Management

The project team uses the Data Explorer and Model Explorer to publish ongoing data and model updates and gather feedback and suggestions from the desert tortoise community. While this workflow is "behind the scenes" it is an important and iterative part of system maintenance. A great part of the utility and credibility of this system depends on its use of the best available data, models, and scientific knowledge related to desert tortoise recovery. The project partners strongly recommend that any future development of the system include, as one task, dedicated resources to continue the ongoing maintenance and updates to system data and models.

C.3.4 Fifth Workflow: Adapting the System for Other Species and Renewable Energy Types

A long-standing goal of this research has been to design the system to accommodate research on other regions, sensitive species and renewable energy types, beyond the current focus on solar energy project impacts on desert tortoise. What makes this possible is that the conceptual model is based on an open standard lexicon for biodiversity conservation developed by conservation experts (Salafsky et al. 2008; CMP 2015). As part of this project, the standard lexicon was formalized as a domain ontology of the public Spatial Decision Support Knowledge Portal (SDS Knowledge Portal; Li 2012). The Desert Tortoise SDSS conceptual model was then formalized as a modified subclass of that biodiversity conservation domain ontology. This provides researchers with access to both the biodiversity conservation lexicon, and the desert tortoise conceptual model in a format that can facilitate adaptation of these frameworks for other species and regions. The sections below provide more detail on this research task.

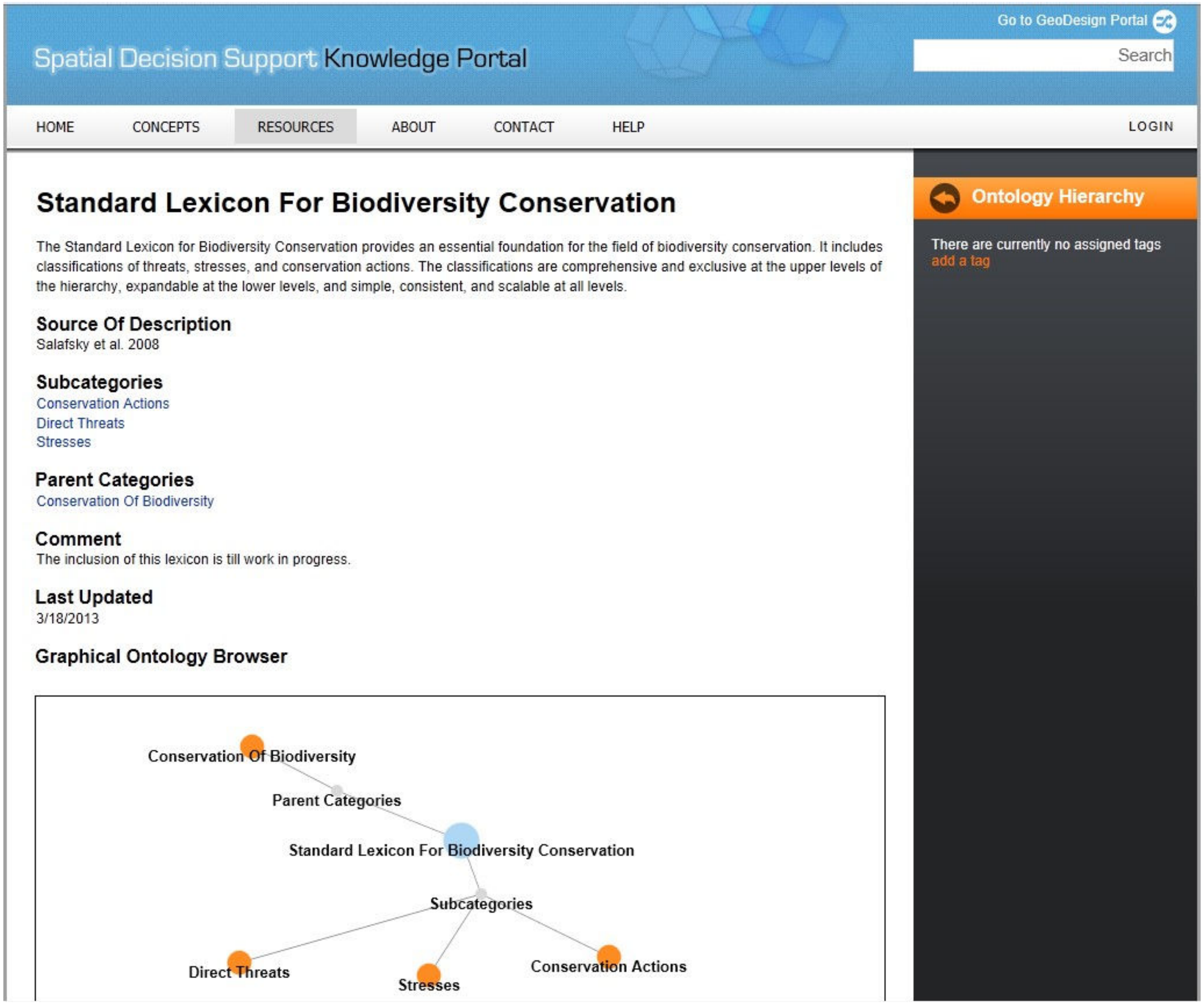
C.3.4.1 Encoding the Standard Lexicon into the SDS Ontology

Each entity of Salafsky's biodiversity conservation lexicon (e.g., threats) became a main ontology branch within the spatial decision support ontology (SDS ontology) in the SDS Knowledge Portal, and the team created a table for each level of lexicon concepts. The rows in these tables contained information specific to that particular threat concept (e.g., energy production and mining threats), such as:

- Concept ID (which includes the ontology prefix and concept name in Camel case, e.g., BiodiversityConservation:EnergyProductionAndMiningThreats)
- Concept English label (e.g., "energy production and mining threats")
- Concept index as originally assigned in Salafsky's lexicon (e.g., "3")
- Concept description ("Energy production and mining threats from production of non-biological resources")
- ID of the parent class concept (e.g., BiodiversityConservation:Threat)
- Other ontology development related information, such as whether this concept is a class (vs. instance)

The project team imported the tables into the biodiversity conservation sub-ontology, to build out the ontology branches for threats, stresses and conservation actions. The team then published a new release of the SDS ontology (Figure C.7). This Biodiversity Conservation ontology can be publically accessed at the SDS Knowledge Portal at: http://www.spatial.redlands.edu/sds/ontology/?n=BiodiversityConservation:StandardLexiconForBiodiversityConservation.

Figure C.7: SDS Knowledge Portal: Ontology Page for Standard Lexicon for Biodiversity Conservation



Main page of the Biodiversity Conservation ontology as integrated in the SDS Knowledge Portal. The page shows the source of the description, related sub-categories and parent categories, comments and date last updated. It also provides a graphical browser for navigating the relationships between the standard lexicon and other elements in the SDS ontology.

Source: Spatial Decision Support Knowledge Portal

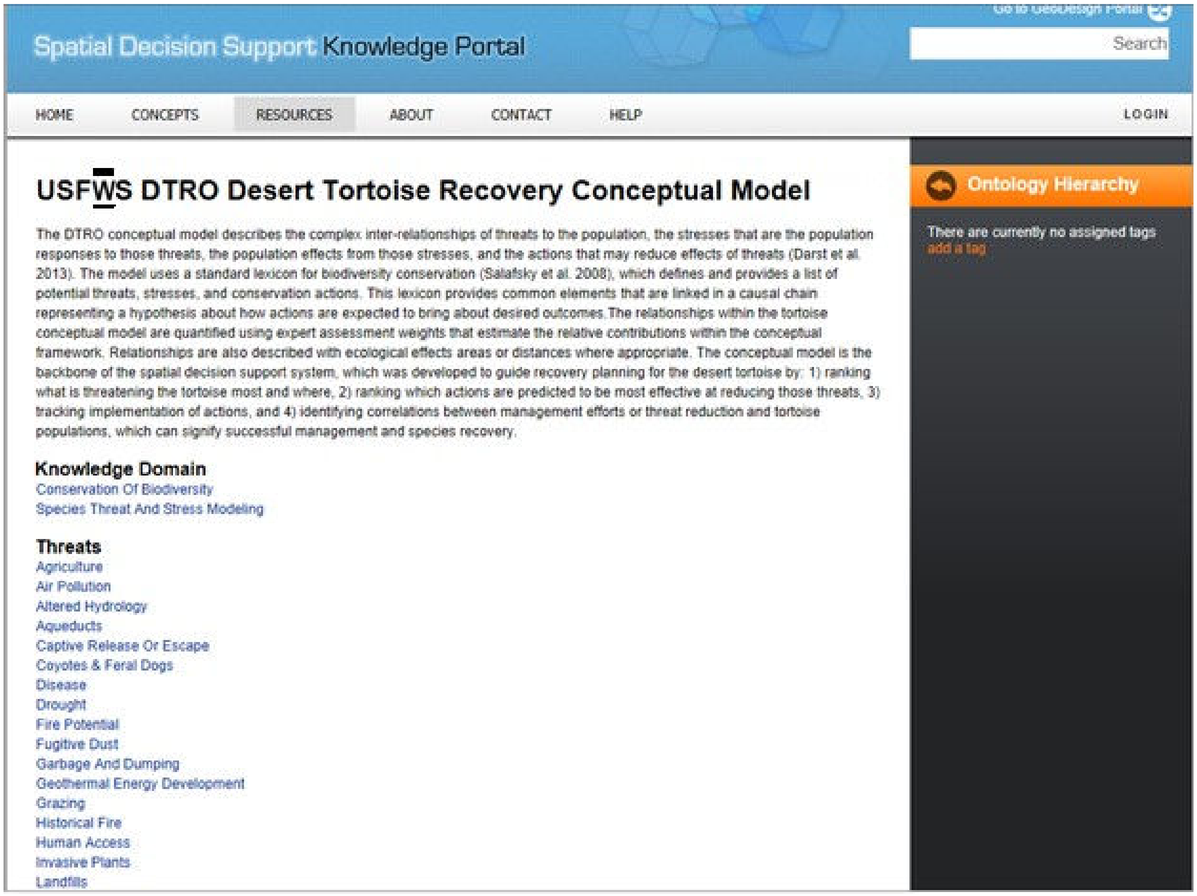
C.3.4.2 Developing the Desert Tortoise Recovery Conceptual Model as a Sub-Ontology

The second task was to "ontologize" the Desert Tortoise SDSS conceptual model, which was built on top of Salafsky's standard lexicon. This involved developing a desert tortoise recovery sub-ontology which imports the biodiversity conservation ontology. Besides the taxonomic relations among concepts, the team coded causal relations among threats, stresses, and recovery actions. Finally, the team encoded spatial directives for computation (e.g., distance decay with decay constant of 3km) as attributes to those relationships. Coding the desert tortoise conceptual model in standard ontology language makes it easier to share and access with organizations that may wish to adapt this model for other species, outside of the Desert Tortoise SDSS and Conceptual Model Manager.

Coding the desert tortoise conceptual model within the SDS ontology required three steps:

1) *Design the "schema" for the desert tortoise recovery conceptual model ontology.* The SDS ontology is written in the OWL Language (OWL Web Ontology Language Overview, 2004). Key design decisions for the desert tortoise recovery conceptual model ontology were: (a) encoding the many relationships in the conceptual model as entities (reification); (b) whether to treat a concept as a class or an instance of a class; (c) relating the concepts in the desert tortoise conceptual model and the concepts in biodiversity conservation lexicon (a corresponds-to relation was used).
2) *Importing the Desert Tortoise SDSS conceptual model.* To semi-automate the import process, the team first exported, in several tables, all the content in the SDSS conceptual model. The team then manipulated the tables into a format that the ontology development tool (TopBraid Composer) could accept as batch inputs. The partners then manually created classes for the entity types and relation types that are implicit in the exports from the Desert Tortoise SDSS Conceptual Model Manager, and the relations among these types. Next, the team connected the new desert tortoise recovery conceptual model ontology to the overall SDS ontology set. Finally, the partners established the derivation relationship between the entities in the desert tortoise conceptual model ontology to those in the biodiversity conservation lexicon ontology.
3) *Release of the desert tortoise recovery conceptual model ontology on the SDS Knowledge Portal.* The results of this work can be accessed on SDS Knowledge Portal (Figures C.8 and C.9) at: http://www.spatial.redlands.edu/sds/ontology/?n=DTROCM:DTROModel.

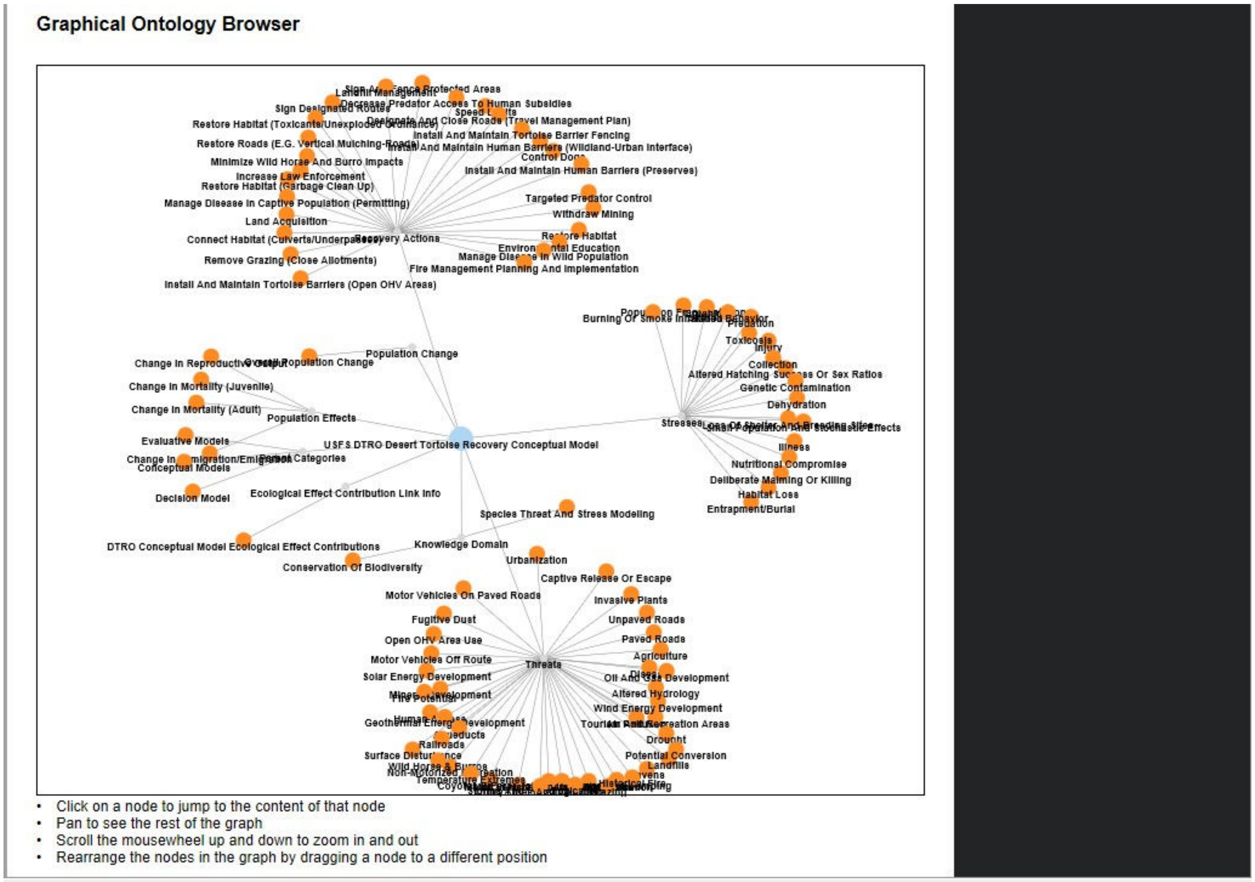
Figure C.8: SDS Knowledge Portal: Ontology Page for Desert Tortoise Recovery Conceptual Model (Top of Main Page)



Top of the main page of the desert tortoise recovery conceptual ontology, as integrated in the SDS Knowledge Portal, showing the description, knowledge domain and threats included in the Desert Tortoise SDSS conceptual model.

Source: Spatial Decision Support Knowledge Portal

Figure C.9: SDS Knowledge Portal: Ontology Page for Desert Tortoise Recovery Conceptual Model (Bottom of Main Page)



Bottom of the main page of the Desert Tortoise Recovery ontology in the SDS Knowledge Portal, showing the graphical ontology browser for exploring the Desert Tortoise SDSS conceptual model.

Source: Spatial Decision Support Knowledge Portal

C.3.4.3 Creating Public Web Services Originating in the SDS Ontology

The final task was to create public Web services that originate in the SDS ontology to make available:

- The core entity and relationships of the biodiversity conservation lexicon to jump start new conceptual modeling; and
- The core content of the desert tortoise species recovery conceptual model.

The SDS Knowledge Portal (Li 2012) enables page requests from a browser, via a REST Web service request to the Ontology Server, to be translated into appropriate SPARQL requests that run against the Allegrograph RDF store to return relevant entity -relation-entity. The Ontology Server parses the triples into a JSON serialization, and returns them to the browser. The design for this work called for four Web services:

1) *Classes and Descriptions*: the core conceptual structure of the biodiversity conservation model.
2) *Entity Descriptions*: descriptions of all entities in the DT species recovery application domain.
3) *Threat-Stress Pairs*: all threat to stress links, whereby a threat contributes to a link in the desert tortoise domain with weights values (nominal, min, max).
4) *Recovery Actions*: all recovery action to (threat, stress) pair mechanisms that the action can reduce or suppress, the effectives weight, and spatial computation directives for that interaction.

SPARQL queries were designed for each of these four Web services (Table C.2), and a test web page created to show the results.

Table C.2: Web Services Supporting the Biodiversity Conservation Lexicon and Desert Tortoise SDSS Conceptual Model in the SDS Knowledge Portal

Webservice	Test Webpage
Classes and Descriptions	http://www.spatial.redlands.edu/allegrograph4/displayClassInfo.html
Entity Descriptions	http://www.spatial.redlands.edu/allegrograph4/displayEntityInfo.html
Threat-Stress Pairs	http://www.spatial.redlands.edu/allegrograph4/displayActionMechPairs.html
Recovery Actions	http://www.spatial.redlands.edu/allegrograph4/displayThreatsToStress.html

Source: Spatial Decision Support Knowledge Portal

The four public web services developed are structured to be sufficient to generate the full conceptual model for the Desert Tortoise SDSS, complete with computational directives (e.g., distance decay with a decay distance of 3km).

Conversely, when working on a species recovery system for a different species, similar SPARQL services can be created to provide the same information, based only on the biodiversity conservation lexicon. Via the desert tortoise Conceptual Model Manager, this would provide the underlying entity-relationship diagrams that domain experts could use to start identifying and quantifying the interactions for that species (as was done at the start of this project). From those causal entity-link-entity diagrams, the Conceptual Model Manager can build out the full conceptual model for that species. If spatial computational directives are included, the entire risk model can be run using the Desert Tortoise SDSS (but for the new focal species) to provide the same spatial analysis of risk to population currently available in the SDSS for the desert tortoise. To complete the circle, similar steps as those described above can be executed to upload a detailed conceptual model for a new species into the SDS ontology for sharing with others.

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